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DEFENSE ANALYSIS: THE DECISION PROCESS

by

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b RESTRICTIVE MARKINGS: N/A
2a. SECURITY CLASSIFICATION AUTHORITY: N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for Public Release: Distribution is Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): N/A	5 MONITORING ORGANIZATION REPORT NUMBER(S): N/A
6a NAME OF PERFORMING ORGANIZATION: Naval War College; 6b OFFICE SYMBOL (If applicable): BD-8	7a. NAME OF MONITORING ORGANIZATION: Naval War College
6c. ADDRESS (City, State, and ZIP Code): Newport, RI 02841-5010	7b. ADDRESS (City, State, and ZIP Code): Newport, RI 02841-5010
8a NAME OF FUNDING/SPONSORING ORGANIZATION: N/A; 8b OFFICE SYMBOL (If applicable): N/A	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N/A
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO: - ; PROJECT NO: - ; TASK NO: - ; WORK UNIT ACCESSION NO: -
11 TITLE (Include Security Classification): Defense Analysis: the Decision Process, Newport, Naval War College, 1985. (Unclassified)	
12 PERSONAL AUTHOR(S): Abell, Keller, and Satterthwaite	
13a TYPE OF REPORT: Selected Reading; 13b TIME COVERED FROM ____ TO ____; 14 DATE OF REPORT (Year, Month, Day); 15 PAGE COUNT: 150	
16 SUPPLEMENTARY NOTATION	

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Systems Analysis, Decision Making, Objectives, Systematic, Systems View, Systems Approach, Alternatives, Cost, Effectiveness, (over)

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

A monograph ottering a decision tramework tor complex problems ot resource allocation. Includes chapters on formulating the problem, the research ettort, evaluation ot alternatives, interpretations of results; implementation and verification once the decision is made.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL: CDR William C. Keller, USN	22b TELEPHONE (Include Area Code): 401-841-3892; 22c OFFICE SYMBOL: BD-8

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

0102-LF-014-6602

18. (Cont.) Implementation, Verification, Decision Making, Risk, Uncertainty, Analysis

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MONOGRAPH

BY

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Naval War College
Newport, Rhode Island

July 1985

PREFACE

This is a book about the process of decision making in the Defense environment. It describes a systematic way to deal with the large and complex problems that face the military executive in the United States Department of Defense or any military establishment in the free world. The value of such a methodology should not be underestimated. The increasingly limited funding available for national defense and the simultaneous growth in the cost of weapons, manpower, operations and maintenance have made it imperative that the best possible use of resources is achieved.

It has been written primarily for middle level and senior military officers who are moving toward leadership positions which carry out the planning of future forces, the programming and budgeting for those forces, and the execution of approved Defense plans and programs. This may be at the national headquarters or in one of the major commands holding responsibility for functional missions or theater operations. Additionally, the material will be very useful to those who support Defense activities, produce Defense related materials and hardware, or teach various aspects of national security affairs. A non-technical style of writing has been used to insure that the concepts and processes are readily understandable across the full spectrum of professional military backgrounds.

The initial motivation for the book began in 1972 when Vice Admiral Stansfield Turner established a totally new curriculum at the Naval War College in Newport, Rhode Island. The Management Department was tasked to use highly complex, real world Defense issues to develop the student's capacity to analyze difficult resource allocation decisions. Three distinct management courses were established the second year, with Decision Process serving as the conceptual basis for the methodology of decision making. The course was renamed Defense Analysis in 1978 and has remained a key part of the war college study in Defense Economics and Decision Making. While considerable written material in support of the course had been collected over the years, it lacked organization and consistency of terminology. This writing effort is intended to fill that need.

This book is an abbreviated monograph, drawn from the expanded text entitled Defense Analysis: A Primer on Decision Making for the Defense Executive which is soon to be published. It was written with several goals in mind. First and foremost, to provide a text at the Naval War College that describes the Decision Process, an effective methodology for rational, analytical decision making in

the Defense environment. There are many books that apply analytical technique or systems analysis to business and industrial problems. There are also many books written about our national security environment and the issues that face the senior leadership of the Defense Department. However, there is no current literature which outlines a prescriptive decision making processes which can be applied in the Defense arena.

Translating the technical complexities of analytical process into concepts and discussions that can be understood across the full range of professional military expertise was the second objective of the book. By screening out the highly quantitative explanations found in most textbooks on analysis and carefully developing each concept and phase of the process, it is hoped that the methodology can be readily assimilated at the executive development level of understanding and become a functional tool for future use. Finally, the authors hoped that by fixing the evolution of this unique decision process at one point in time, it would provide a solid foundation for future research and development. Unquestionably it is an evolving concept--with many inconsistencies and perturbations yet to be explored.

This book is best used in the seminar environment where examples and case studies can be used to explain concepts and illustrate their application in actual Defense decision situations. The optimum learning outcome will be gained where the material can be mixed with the background of the experienced military executive and instructors knowledgeable in both decision making concepts and practical application. Hopefully it will serve well as a reference book for those actively engaged in making the hard, real world choices of Defense resource allocation.

The authors owe a debt of gratitude to so many individuals who have helped to make this undertaking a reality. Certainly to those who provided administrative and graphic art support. And to family members who put up with the long hours away from home and many moments of irritability. But most of all, we wish to thank the Defense Analysis faculty and countless students at the Naval War College, both past and present, who have contributed immeasurably to the ideas set forth here. A more helpful and knowledgeable "sounding board" could not have been found.

John T. Abell
William C. Keller
F. G. Satterthwaite

ABOUT THE AUTHORS

Colonel (Retired) John T. Abell, U.S. Air Force

Colonel Abell recently retired from the Air Force after 30 years of rated duty, mostly with Strategic Air Command, Tactical Air Command and Pacific Air Forces. He served as Wing Commander at Yokota Air Base, Japan and National Military Representative to Supreme Headquarters, Allied Powers Europe (SHAPE). He established the Decision Process course at the Naval War College and was serving as the Defense Analysis Coordinator at retirememt. He has a Bachelor Degree in Economics and a Masters of Business Administration from Arizona State University.

Commander William C. Keller, U.S. Navy

Commander Keller is a surface warfare officer who has served in many types of combatant ships--including a gunboat, minesweeper, destroyer, and cruiser. He has commanded the research ship, Alacrity (AG 520) and the frigate Harold E. Holt (FF 1074). A financial management sub-specialist, he recently was assigned to the faculty at the Naval War College in the Department of Defense Economics and Decision Making. He is a graduate of Colgate University (BA, Psychology) and received his Masters degree at the Naval Post Graduate School in Monterey.

Dr. F. G. Satterthwaite, Monterey Institute of International Studies

Dr. Satterthwaite has combined a strong background in Decision Science with a broad experience with the U. S. Navy and other government related activities. Having taught at both the Naval Academy and the Naval War College for several years, he has had a wealth of experience in such areas as war gaming, Anti-Submarine Warfare operations and management information systems for the Naval Recruiting Command. He has a PhD in Public Management, a MS in Mathematics from American University and a Bachelor's Degree in Physics from Fordham University. He is a Captain in the U.S. Naval Reserve and is the Commanding Officer of a reserve unit in California.

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CHAPTER I

INTRODUCTION TO DEFENSE ANALYSIS AND THE DECISION PROCESS

Defense Analysis is a framework for decision making that combines the expertise and judgment of the uniformed Defense executive with a rational decision process and related techniques which strive for optimum resource allocation.

The initial foundation for Defense Analysis can be found in several disciplines that have developed over the past seventy-five years. A more detailed evolution of this framework will be discussed in subsequent chapters. It is sufficient at this point to say that important concepts from scientific management, performance budgeting, cybernetics and operations analysis all contributed to the development of a "systems approach" to decision making--an approach typified by Defense Analysis. C. West Churchman, one of the innovators of this concept, defines the systems approach as "one which characterizes the nature of the system in such a way that the decision making can take place in a logical and coherent fashion and that none of the fallacies of narrow-minded thinking will occur." 1

As a refined variation of the systems approach, Defense Analysis can be described by the following principles:

1. Using a systems view, the environment surrounding any decision is seen as a series of systems that interact with each other.

2. All activities within these systems are goal-oriented and thus the objective is the focal point of decisions.

3. Alternative ways to achieve goals must be carefully evaluated to insure all relevant factors are considered.

4. Solutions must consider uncertainty as well as the external environment.

5. The activity of deciding is a dynamic process with a built in self-correcting or feedback mechanism.

6. Uses professional military judgment.

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1 C. West Churchman, The Systems Approach (New York: Delacorte Press, 1968), p. ix.

Figure 1 summarizes the overall structure of Defense Analysis by depicting the three essential elements that lead to its success in dealing with decision making in the Defense arena. Let us briefly examine these three elements by first looking at the uniformed Defense executive as a primary source of professional military judgment. Then we will outline the ways that Management Science tools and techniques can assist in decision making. Finally, we will point out why a well-defined and useful process is essential to rational decision making.

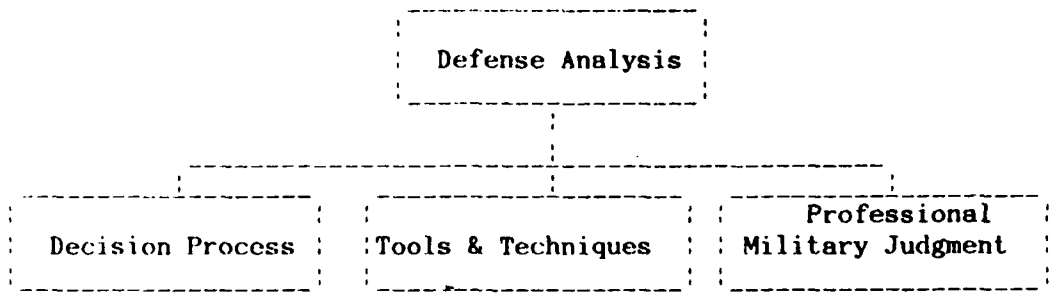

Figure 1: The three elements that make up Defense Analysis

Who Is the Uniformed Defense Executive ?

The uniformed Defense executive has a well-developed background of military experience, sufficiently tested and proven to establish credible military judgment. This judgment cannot be developed from a textbook but must be formed by exposure to a broad range of military experiences: the combat environment, real or simulated, where judgment under stress has been tested and the value of human life has been indelibly etched; command and staff assignments, where the importance and pervasive nature of the mission has been unmistakably learned; and finally the managerial tasks, where the officer has learned the meaning of limited resources and ever-increasing requirements. This professional military judgment which is the "strong suit" of the Defense executive is a critical element in the Defense Analysis framework.

Being a proven decision maker is a second quality of the uniformed Defense executive. Through education, training and operational experience, the military officer has faced the reality of making decisions; often having to decide with little available information or time and paying for bad decisions by living with the consequences. Failure weeds out the less accomplished decision maker. The promotion system sees to that. With rare exception, those who move through the ranks do so by making correct choices. In contrast to the business world, DOD does not hire from outside sources a "successful" military officer to take over at middle or top levels of management or command. Officers start at the bottom

of a pyramid-shaped grade structure and move toward the top, developing expertise and skills in ever-broadening areas of responsibility. Normally, the type of uniformed Defense executive to use the Defense Analysis framework is one who has graduated from the operational world of "doing" and is ready to apply the judgment and experience gained there to the vastly different environment of decision making. As W. E. Turcotte observes:

> For much of their careers, military officers seek to master at least two major activities calling for different types of skills. The first activity is warfighting proficiency. The second is choosing and supporting forces for possible war. Mastery of increasingly complex warfighting skills dominates perhaps the first 16 years of an officer's career. Indeed this complexity tends toward an ever narrowing understanding of the way all forms of military power and resources can be integrated into what might be referred to as a balanced choice of forces. As officers become more senior, their efforts increasingly involve major resource allocation decisions. Much of their time is involved in choosing, acquiring, and then supporting military force. 2

Finally, it is worthwhile to list capability that the uniformed Defense executive is not required to have. This individual certainly does not need to be a professional analyst; the highly trained specialist who is an expert in quantitative processes and sophisticated models. The term uniformed Defense executive is defined by the capability of most successful military officers who have progressed through the ranks and are now ready to face major decision making responsibility in the Department of Defense. They are the ones that add professional military judgment to the Defense Analysis framework.

How Do Tools & Techniques Fit in the Defense Analysis Framework?

The various quantitative tools and techniques that are available to deal with complex resource allocation decisions probably do more to cause uniformed Defense executives to shy away from all types of analytical processes than any other single factor. What are these tools and how are they involved in the Defense Analysis framework? Indicated previously, a key factor in the evolution of the systems approach and Defense Analysis has been the integration of several disciplines which all contribute to the solution of complex problems. Most tools and techniques included in the framework of Defense Analysis have come from the Management

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2 William E. Turcotte, "Leadership vs. Management," Washington Quarterly, Winter 1983, p. 47.

Science and Operations Analysis disciplines. They are, for the most part, quantitative processes designed to solve the mathematical computations that occur in most Defense decisions. These tools and techniques help the decision maker in such ways as: clarifying and simplifying data needed to define the values of alternatives (i.e.,statistics, forecasting); providing techniques to actually compare the choices being considered (i.e., linear programming, simulation); or serving as tools for carrying out decisions that have already been made (i.e., networks, sampling). These quantitative processes can be as simple as the averaging of many data points into one single value (statistics) or as complicated as Global War Games that can exceed the capacity of large computers.

There is one question that worries many officers. How will the uniformed Defense executive, who is not an analyst, know how and when to use these tools and techniques? With few exceptions all of these quantitative techniques can be understood at a conceptual level, leaving the technical competence to a specialist. In fact, it is far more important that the senior officer understand the concept behind a particular tool than how to actually apply the technique. As the resource manager, he or she is often the only one that is really aware of the total environment surrounding a decision and how a particular quantitative technique could be used to evaluate the possible alternatives. It doesn't matter that the executive cannot handle the mathematics necessary to compute the actual outcomes. What is important is the knowledge of how and when to match up the appropriate technique with the decision to be made and what to do with the results these tools can produce.

Why Do We Need a "Process" for Making Decisions?

When we speak of making a decision we often think of the problem faced or the choice to be made. Rarely do we consider the process which made the choice. Yet, prior to all decisions involving normal behavior, some form of reasoning process takes place. It is understanding this process leading up to the choice that is essential.

For quick, simple or repetitive situations the decision process is a mental one. As we move toward larger and more complex decisions, we eventually exceed our capacity to organize and evaluate all of the factors at once. At these more difficult levels of decision making, we are forced to use external means such as written calculations and notes or diagrams to assist the mental activity. At the point where decision making is transferred from a mental effort to an externally structured process, the need to be explicit about that process becomes critical. Having a definitive process not only helps to understand the rationale behind the decision, but it also assists in conveying this logic to others.

WHAT KINDS OF DECISIONS ARE APPROPRIATE FOR DEFENSE ANALYSIS?

Every day literally thousands of decisions are made on behalf of our nation's defense. Some are quite simple ones such as the decision to either turn off the lights in the Pentagon to conserve power or leave the lights on to reduce bulb failure rate caused by turning lights on and off. Some decisions are so complex and far-reaching that they affect the lives of millions of people and potentially the course of history.

Certainly, the Defense Analysis framework is not appropriate for many types of decisions made each day in the DOD; decisions on how to react to political and military events, problems of internal defense policy, questions of "rightness" or "inappropriateness." Very few decisions in these areas are suitable for the logic structure of Defense Analysis. However, a great number of issues faced in the Department of Defense are resource allocation decisions, and these are the kinds of choices for which Defense Analysis is ideally suited.

What are "resource allocation" decisions? Obviously, they deal with resources; those decisions of how to best use the available assets to meet national security objectives. These assets may be the dollars available in the Defense Budget or the already existing equipment, logistics and manpower where the decisions center around how or where to use the assets. The resource to be allocated may even be time; the question being how can we achieve several tasks within a certain time limit? In Table 1 on the next page E. S. Quade summarizes the types of decisions where an analytical approach such as Defense Analysis can be very useful. 3

These allocating decisions are required in the Department of Defense because resources, from manpower to hardware, are always limited in quantity and choices must be made between competing requirements. The reality of limited resources is fundamental to the entire concept of making decisions involving the use of resources, whether it be national resources or the personal assets of an individual.

AN OVERVIEW OF THE DECISION PROCESS

Discussion of the qualities of the uniformed Defense executive and a look at some of the tools and techniques available for decision making are two very fruitful areas for a more intensive study of the Defense Analysis framework. However, the focus will be

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3 E. S. Quade and W. I. Boucher, Systems Analysis and Policy Planning: Applications in Defense (New York: Elsevier, 1968), p. 2.

Problem Areas	Examples
Management of Operations	Determining the inventory at a parts depot.
	Establishing maintenance procedures for a ship's nuclear power system.
Choice of Tactical Alternatives	Determining the most effective armament for an interdiction mission.
Design and Development Systems	Selecting a preferred set of space boosters.
Determination of Major Policy Alternatives	Deciding between a policy of military superiority and one of parity.

Table 1: Types of Defense Resource Allocation Decisions

on the most critical part of Defense Analysis, the concepts and application of a process for making decisions. What is needed is a methodology for decision making that is designed specifically to analyze complex problems and issues in Defense. The name that has been given to such a methodology is the Decision Process. This format for decision making has been developed at the Naval War College over the past twelve years and is advocated because of its ability to help focus on the difficult aspects of Defense decision making: identifying objectives, explicitly measuring quantitative elements in the decision, determining the relevance of subjective factors and finally, providing a method for combining the quantitative and subjective factors that must be considered in the decision.

Decision Process Defined.

The Decision Process is a systematic way to assist the decision maker define objectives, identify alternatives and evaluate their quantitative and subjective consequences, and then follow up when the decision is made.

A brief discussion of three of the key words in this definition will help to understand the overall concept. The first word is "process" and refers to the dynamic nature of decision making. It emphasizes that "making a decision" does not occur at a moment in time but is a series of activities that terminates with the selection of the preferred alternative and the implementation of that course of action. This term avoids the connotation of being a static framework where one plugs in data, turns a crank and out comes the answer. Also implied in the meaning of "process" is the

idea that, while there is a reasonable sequence of activities that can be followed, one must always be ready to return to an earlier stage in the process to add to or revise. This is the concept of "iteration" and will be further developed in a later chapter.

Another word to be further considered in the definition of the Decision Process is "assist." No one should hold the view that the Decision Process, or any methodology for dealing with complex decisions, will automatically produce the "right answer." The individual responsible for allocating the resources involved in the decision remains the decision maker, and the objective of the Decision Process is to assist in that decision. Assistance is provided by illuminating objectives, identifying the relative difference among alternatives and providing a structure for organizing all the relevant information. Another equally important meaning for "assist" is defined by how the Decision Process helps the decision maker. First of all, it can assist by serving as a personal thought process, the mental structure by which one personally analyzes the decision to be made. This might be done totally within the mind by systematically thinking though the phases of the process and reasoning accordingly, or by the use of written notes and computations. Secondly, the Decision Process can assist by providing a structure for an analysis to be done by others in support of the decision maker. In either case the process will assist in communicating the results more clearly to the person who will be making the decision.

The third key concept in the Decision Process definition is the idea that "follow-up" is a part of the decision. Many unfortunate experiences in the Department of Defense teach us that making a decision does not necessarily mean that the resource allocation will occur as decided. The size of the decision, the geographic span of control, the time span of implementation and the mobility of personnel are but a few legitimate reasons why things often do not happened as they were decided. Including follow-up in the decision process is a very essential part of making an effective decision.

Characteristics of the Decision Process

Because the Decision Process is the "operative" part of the Defense Analysis framework, many of the qualities of the systems approach can be clearly seen as characteristics of this decision making format.

The following four attributes characterize the nature of the process:

- an economic foundation

- a rational process

- a systems view

- a systematic method

An Economic Foundation. The Decision Process has its roots in one of the most elementary economic principles--the law of scarcity. Paul Samuelson, the often quoted writer of general economic theory, summarizes an initial chapter in his basic economics book by concluding that this law is "the fundamental fact of all economic life: With limited resources and technology, standards of living are limited. Economic goods are scarce, not free. Society must choose and ration among them, because not all needs and desires can be fulfilled." 4 He points out that, because of this economic law of scarcity, man must solve three problems: what goods and services should be produced, how should resources be used to produce these goods; and to whom should the goods be distributed? Thus, decisions requiring resource allocation are caused by this law. Effectiveness in making those choices strongly affect his economic-well being and satisfaction with life.

Closely related to the law of scarcity is another basic economic principle. It is the concept of optimization. Because resources are limited and several alternative uses for them are possible, the decisions that are made should optimize the use of those resources when trying to achieve desired objectives. It provides the economic rationale for measuring the "goodness" or "badness" of any decision. This optimality is normally achieved by making choices in one of two ways: either by selecting the most benefit for a given amount of resources being used; or getting the desired level of benefit by spending the least amount of resources.

A Rational Process. The characteristic of rationality is central to the nature of the Decision Process. Four qualities of the Decision Process underscore this characteristic of being rational. First of all, the process is goal-oriented, always focused on choosing the alternative which best meets the objective. This is, of course, one of the prime determinants of rational behavior. Secondly, it is based on reality rather than on theoretical or hypothetical premises. Thirdly, the process considers all facts available for the decision, not biasing the choice by ignoring quantitative or subjective factors that will affect the outcome. Finally, the Decision Process is rational because it is predictable. When the process repeated by the same person or done by another individual using the same set of data, it should produce a similar solution.

A Systems Viewpoint. One of the most difficult parts of decision making, especially where complex problems are involved, is

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4 Paul A. Samuelson, Economics, 11th ed. (New York: McGraw-Hill, 1980), p. 34.

getting everyone to see the situation from the same perspective. One way to overcome this divergence in perception is to settle on a common viewpoint--to see a decision situation as well as the environment that surrounds it as a system.

A system can be defined as a regularly interacting or interdependent group of items forming a unified whole and serving a common purpose. Implied in this definition is the idea that some structure or device takes in resources, acts upon them and produces some desired outcome; thus the concepts of input, process and output of a system. All systems are part of and interact with larger systems and have sub-systems of their own.

A systems view helps to focus in on that which is relevant by describing only those systems directly involved in the choice. Application in the Decision Process is very straight-forward. When facing a resource allocation decision, we first identify how the system involved in the decision is structured and operated, and what its surrounding environment is like. We then determine the resources flowing into the system and what kind of benefits would flow out of the system for each alternative that might be selected. For instance, if called upon to decide which Surface-to-Air Missile to buy, we must first envision what system that missile operates in before evaluating the various options. Is it a close-in ship defense system, an air base perimeter defense system or a barrier defense system for the central front in Europe? Identification of that system and the environment it operates in (such as the overall fleet defense system, a tactical air control system or a theater ground defense system) is essential to choosing the best missile for the job.

A Systematic Method. One of the most obvious characteristics of the rational man is that of being systematic.7 Such words as predictable, business-like, methodical and orderly are all synonyms describing his typical behavior pattern. There are several qualities of the Decision Process that are suggested by this characteristic of being systematic:

1. It is an orderly process; one which uses a sequential, step-by-step building block approach to solving a problem.

2. It follows a predetermined format; one which serves as a guide for analyzing the decision and permits someone else to duplicate the original effort.

3. It has a starting point and a finish; starting with the objective to be achieved and ending with the preferred alternative and the way it can be implemented.

4. It is comprehensive and thorough; considering all relevant factors and their sensitivity to change. To be sytematic not only requires a procedural orderliness but a willingness to

consider all of the factors that might affect the choice of alternatives.

Is the Decision Process Reinventing the Wheel?

There are many methodologies with similar characteristics to the Decision Process that have already been developed to help Defense executives make decisions. Why do we need still one more approach to decision making? After all, most would agree that good decision making can be done by a simple five-step process:

1. Recognition of the problem.
2. Collection of necessary information.
3. Development of possible solutions.
4. Analysis and comparison of these solutions.
5. Selection of the best solution.

Within the military environment there are two well-established and useful approaches to decision making that use all of these steps: the Staff Study and the Commander's Estimate of the Situation. They have both been used by many generations of military operators and planners to arrive at effective and well thought out decisions.

Then why offer one more process for decision making? There are at least two important reasons. First, the traditional military formats for decision making often do not meet the demands of complex resource allocation problems. They are designed primarily for decisions where the objective or mission is very clearly stated and where the sets of alternatives to be considered usually come from prior developed doctrine or standard operating procedures. The second reason for developing a new decision process is that the existing decision structures that have been specifically developed to deal with complex, quantitative decisions (such as systems analysis and cost-effectiveness analysis) normally become too technical.

Thus the Decision Process is not an attempt to reinvent the wheel by arbitrarily creating a new set of "buzz words" for already existing decision making processes. While the process generally follows the five basic steps found in most rational models, its unique design has been specially developed to deal with a much broader range of problems than those appropriately solved by the Staff Study, the Commander's Estimate and other types of decision formats.

The Decision Process provides a structure for dealing with high-level, complex decisions of force choice and strategy

development. It is ideally suited where resource allocation choices created by limited national resources require decisions to be made which optimize the use of these resources. The process is also specifically designed to deal with decisions where extensive quantitative factors are involved and where both quantitative and subjective factors must be considered in the decision. It also combines procedures for following up on the execution of long-term choices.

PHASES OF THE DECISION PROCESS

There are a great many activities in life that are performed as a single, harmonious effort and yet can be subdivided into separate elements for the purposes of analysis and improving the overall activity. The Decision Process is a coordinated event that has several identifiable phases which make up the overall activity. To define the concepts involved and to help understand this unique approach to decision making, the Decision Process is divided into five phases: Formulation, Search, Evaluation (of both quantitative and subjective factors), Interpretation, and finally Implementation and Verification.

Although the phases of the Decision Process will be covered in detail, a brief summary of each phase will show how they all fit together in the overall process.

The Formulation Phase. This phase is referred to as the conceptual phase because its purpose is to organize the major elements of the decision to be made and identify all factors which will affect the order in which the alternatives are ranked. Figuring out what decision is to be made is a reasonable place to begin. Of course, it is always good to know who the decision maker will be as well as what objective is to be achieved. It is here that a systems view is developed and where we try to determine what qualities we could use to evaluate the benefits and costs resulting from choosing an alternative. Once the Formulation Phase is completed, we are ready to collect data and begin evaluating the choices available.

The Search Phase. It is during the Search Phase that we try to collect all of the information needed to later evaluate the alternatives and prepare to make a decision. Our primary task during this phase is to use the data to define alternatives which may effectively meet the objective. With the wealth of information available in today's world of computers, it is very important that we screen out all information that is not necessary, saving only relevant data for the next phases.

The Evaluation Phase. It is in this phase that we actually compare alternatives, first by evaluating the quantitative parts of

each alternative and then by evaluating the various subjective factors that cannot be compared numerically. Quantitative analysis will require a model to be developed which represents the system in which the decision is to be made. With this model we will measure the benefit and cost that would result from choosing each of the alternatives. We also want to test each option to see how sensitive they might be to any uncertainty in the data we used. To evaluate subjective factors we must use professional military judgment and then try to show the difference between alternatives with some form of weighting procedure.

The Interpretation Phase. Interpretation is probably the most important phase for determining the quality of the decision. First of all, we must interpret the results of the quantitative analysis, deciding how important are the relative and absolute differences between alternatives. Then we devise some way to combine the outcome of the subjective evaluation with the quantitative results and display this information in a useful format. Finally, we draw conclusions from all of the preceding effort and either decide or make a recommendation for a decision.

The Implementation and Verification Phase. This final phase of the Decision Process applies both before and after the decision is made. Prior to choosing, we carefully consider how feasible it is to implement each alternative, weeding out those options that are not possible to carry out. When the decision is made, it cannot be assumed that the selected alternative will be carried out. A plan of action is developed which translates all of the factors in the analysis to activities which implement the decision. Verification not only insures that the decision is being carried out but that it conforms to pr]-determined performance standards. It serves as the feedback loop for implementation, identifying and correcting variation from the desired course of action.

SUMMARY

A major portion of the responsibility for providing effective leadership and management in the Department of Defense rests squarely on the shoulders of uniformed Defense executives. Their ability to deal successfully with major resource allocation decisions will be determined to a great extent by their ability and willingness to use methods that are designed to cope with complex, unstructured problems. Defense Analysis provides just such a framework for decision making by combining expertise and judgment, various tools and techniques useful for solving quantitative problems, and a decision process which can identify proper objectives and permit evaluation of the relevant quantitative and subjective factors affecting the choice of alternatives.

The process that describes how decisions are made becomes of major importance once the complexity of the problem goes beyond the mental capacity of the individual decision maker and must be written or as part of a group effort. The Decision Process is a very useful way to assist the decision maker identify objectives, explicitly evaluate the alternative courses of action and follow up once the decision is made. The characteristics of the process include such concepts as: an economic foundation, rationality, a systems viewpoint, professional military judgment and a systematic method.

CHAPTER II

THE SYSTEMS APPROACH TO DECISION MAKING

The word "system" identifies so many things in our daily life, but rarely do we look behind the term to see the system concept involved. There are natural systems like the solar and weather systems. There are physical systems like the telephone, computer and Defense weapons. Management, betting and information systems are all conceptual types. Each day we function as a part of some type of system, whether it is educational, business or an operational one like a missile defense system. We manage Defense resources with the Planning, Programming and Budgeting System and such organizations as the Air Force Systems Command and the Naval Sea Systems Command. In each of these examples there are one or more systems that describe a set of relationships that give purpose to that activity.

THE SYSTEM AND SYSTEMS VIEW

In this chapter we will use the word "system" in three ways: as the term itself, as a systems view, and as a systems approach. "System" refers to the related set of activities that produce some desired outcome. A "systems view" is a descriptive term characterizing how one may perceive the relationship of factors in a given situation. A "systems approach" is a prescriptive term which outlines a methodology for affecting a change in the system through the process of decision making (ie, the Decision Process is a systems approach to making better decisions.)

What Is a System?

Many authors have discussed the idea of a system using definitions ranging from very simple to those which are overly complex. For instance, Stafford Beer suggests that "anything that consists of parts connected together will be called a system." 1 On the other hand, Johnson, Kast and Rosenzweig say, "A system is an

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1. George A Steiner, Top Management Planning (New York: Macmillan, 1969), p. 391.

organized or complex whole; an assemblage or combination of things or parts forming a complex or unitary whole." 2 To be consistent with concepts used in the Decision Process, we will use the following definition:

A SYSTEM IS A SET OF RELATED PARTS AND ACTIVITIES DESIGNED TO USE RESOURCES TO ACHIEVE AN OBJECTIVE.

This is a useful description as it brings together three key ideas that define the overall concept. A system is made up of parts or components which could also be described as smaller systems or subsystems. These parts perform activities or functions which contribute toward the objective of the system. All components and activities are related to each other in a specific and productive way to form the overall system.

An Input-Output Approach. The portion of the definition which refers to the "use of resources to achieve an objective" describes the input-process-output quality of all dynamic systems that have been designed to accomplish a specific purpose. Inputs are those elements which enter the system. They are the resources to be consumed or transformed and thus represent the "cost" of operating the system. System processes are the activities and relationships between the components. It is through these processes that resource inputs are changed into the productive output of the system. Output describes the benefits produced by the process which makes possible the attainment of objectives. The elements that lie outside the system (in the sense that they are not inputs, internal processes, or outputs) are considered part of the external environment. Churchman describes these "externalities" as something "that the system can do relatively little about its characteristics or its behavior. Environment makes up the things and people that are 'fixed' or 'given' from the system's point of view." 3

Open/Closed Systems. This internal-external relationship is fundamental to the concept of open and closed systems. An open system maintains itself while the resources which enter it keep changing. The system is influenced by, and influences, its environment. A closed system, by definition, has no interaction with its environment. Rice and Bishoprick point out how a perspective of open and closed systems affect analyses:

> An open system permits interaction of components across the outer boundaries of the system. It is therefore, much more realistic, but much more difficult to use as

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2. Richard A. Johnson et al., The Theory and Management of Systems 3rd ed. (New York: McGraw-Hill, 1973), p. 4.

3. Churchman, p. 36.

> an analytical technique, since component contributions are not all completely determined by other components within the system.
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> A closed system is a hypothetical construct. They do not exist in reality. But closed system analysis as a way of thinking about the interaction of components is extremely useful. 4

Therefore all systems are open systems because they exist in an environment which affects their operation in some manner. If we are to avoid having to deal with the entire world when we want to make a decision, then we must partially "close" the system arbitrarily in order to be able to deal only with the factors that are directly relevant to the decision. Thus, when considering the best destroyer to use for convoy protection, we know that underway replenishment, sea surveilance by air, and embarkation/de-embarkation are all parts of the open system referred to as a convoy system. However, for the purposes of decision making we may wish to "close" the system to consideration of only the destroyers and how they can provide protection.

Hierarchy of Systems. There is one final point to be made about systems. All systems are subsystems, since all are contained within some larger system. Herbert Simon describes this hierarchy of systems as being "composed of interrelated subsystems , each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem." 5 Therefore, when we are describing a system in which a decision must be made, we should be aware of its relationship to higher systems and to the sub-systems that support it. Otherwise, it becomes very easy to cause systems to work at cross purposes with each other rather than toward one common objective.

What Is a Systems View?

Now that the concept of a system has been defined, let us turn to the notion of a "systems view"--that is, describing our perception of the world as a systems construct. This is opposite of the often used problem solving approach of cutting the problem down to size. The systems view recognizes the significance of synergism,

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4. George H Rice, Jr and Dean W. Bishoprick, Conceptual Models of Organization (New York:Appleton-Century Crofts, 1971), p. 164-165.

5. Joseph A. Litterer, Organizations: Systems, Control and Adaptation: Volume II (New York: Wiley & Son, 1969), p. 99.

that a whole composed of various parts may be quite different from the simple sum of its parts. Johnson, Kast and Rosenzweig compare the systems view with the more typical analytical approach. "While much research has been focused on the analysis of minute segments of knowledge, there has been increasing interest in developing larger frames of reference for synthesizing the results of such research. Thus attention has been focused more and more on overall systems as frames of reference for analytical work in various areas." 6

Characteristics of a Systems View. One way to summarize the systems view would be to point out beneficial characteristics of this perspective. Let us suggest at least four qualities.

1. A Wholistic viewpoint. We can understand the parts of a system much better when we are more aware of how the whole system operates. Furthermore, because the system in question is but a subsystem of a hierarchy of systems, there is considerable value in also knowing the objectives of the higher system and how it operates.

2. A Goal orientation. The types of systems being considered are those that are purposefully developed. They involve the input of resources and the output of productive benefits which seek to achieve defined objectives. These goals provide an standard for measuring performance of the system.

3. A Consideration of all factors. The goal of a systems view is to take into account all of the factors relevant to the decision being made. While this sounds "common-sensical" it is, in reality, completely impossible. As Steiner points out, " in this world everything is connected with everything else and no useful analysis can take into account everything. Obviously, any practicable systems approach...must, therefore, concentrate on a limited number of the most relevant factors. 7 With this caveat in mind, the systems view accepts the reality of the open system, identifying both the internal and external environment of the situation. Both quantitative and qualitative factors are considered, tempered by the fact that uncertainty is a prime determinant of their accuracy.

4. Recognition of a dynamic, systematic activity. The final characteristic of a systems view emphasizes qualities that are representative of scientific insight. These would include a definable structure that produces effective and efficient results, a functioning that is orderly, internally harmonious, open and explicit. A systems view is repeatable, that is, the results of the system can be verified. The time context of this view of reality is

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6. Johnson et al., p. 5.

7. Steiner, p. 391.

in the future, where control of the system can take place. Most frequently this change is determined through the use of a model which serves as a simplified replica of the real world system.

EVOLUTION OF THE SYSTEMS APPROACH TO DECISION MAKING

As stated earlier, a systems approach is a prescriptive term outlining a methodology for changing the system through the process of decision making. Churchman, one of the earliest authors to use the term, says that "in the plan for the development of a system, we throw in as a component the activities that determine the overall objective and the justification of each of the subsystems, the measures of performance and standards in terms of the overall objective, then the whole performance constitutes a 'systems approach' to the problem...." 8 During the past thirty years the systems approach has risen from the advocacies of a few academicians to application across a broad spectrum of scientific, industrial and governmental activities--the most notable being the Department of Defense.

A Historical Background of the Systems Approach in DOD

The evolution of the systems approach in the Department of Defense resulted from a confluence of ideas from several academic disciplines. Three disciplines were central to the development: scientific management and the evolution of budgeting; cybernetics and the concept of self-correcting mechanisms; and economic analyses for the support of capital budgeting.

The use of scientific management began at the turn of the 20th century. F. W. Taylor set out to measure workers performing various tasks at Bethlehem Steel Corporation, developing work standards from these measurements. These standards were then used to organize and control production. From this work the idea of budgeting activities began to evolve. Budgeting has moved through three distinct phases. Budgeteers first began setting limits for expenditures and holding the organization to those limits. Secondly, from Taylor's work came performance budgeting, where work measurement and efficiency became the focus of the budget. Finally, budgeting moved to its third stage where planning became paramount. Expenditure control and management were handled in a matrix of appropriations, tied to planned objectives and an information system that provides data on each element in the plan.

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8. Churchman, p. 8.

The second discipline began to develop during World War II when the U. S. Navy investigated fire control systems that used radar to help calculate where to aim the next salvo. Norbert Weiner of M. I. T. developed the ideas of feedback and control loops as a means of correcting the performance of such systems. Cybernetics, as this process of controlling systems was labelled, were subsequently applied successfully to many military systems. One of the most notable applications of control theory was the pressurized water nuclear reactor which used a negative temperature differential to control the flux of atomic particles in the reactor.

The concepts of economic analysis developed throughout the first half of the twentieth century when ideas of rationality, utility and allocation of resources under scarcity came together to form a cohesive theory of economic behavior. These concepts were all considered useful for making economic decisions in government and soon became fundamental to its operation. Capital budgeting, a contemporary branch of economic theory, dealt with resource allocation decisions over time and became very helpful in making long-term decisions regarding military weapon systems.

All three of these disciplines matured during approximately the same time period. At the RAND Corporation in the late fifties and early sixties, they evolved into two distinct systems approaches for decision making: Systems Analysis and the Planning, Programming and Budgeting System. When Mr. Robert MacNamara became Secretary of Defense in 1960 he brought both systems approach processes to the Pentagon.

Systems Analysis. Systems Analysis is the most famous form of systems application and has continued to be an integral part of the Defense decision structure. While the organizations known as "systems analysis shops" (Program Analysis and Evaluation for OSD and the Army, Studies and Analysis for the Air Force, and OP-91 for the Navy) have had their ups and downs in credibility and influence, there is no question that the systems approach as a process has had widespread use in all the services.

In what ways does this methodology illustrate the use of the systems approach in decision making ? In the following definition of systems analysis the underlined terms emphasize the systems view characteristics:

> Systems analysis, as the term is intended to be understood, can be characterized as a systematic approach to helping a decision maker choose a course of action by investigating his full problem, searching out objectives and alternatives, and comparing them in the light of their consequences, using an appropriate framework--insofar as

possible analytic to bring expert judgment and intuition to bear on the problem. 9

Unfortunately, DOD Systems Analysis has been often criticized in the past ten years. Much of it is well deserved. However, most of the failures of this systems approach have been through faulty application by practitioners with little military experience rather than a failure of the overall concept. Three problem areas existed in past DOD practice of systems analysis:

1. Sometimes the wrong objectives were chosen because of the propensity to look for "measurable" objectives. What can be measured became the system objective instead of deciding on the objective first and then figuring out how to measure it.

2. Often the wrong people were involved in the decision process. In the early years of Systems Analysis only civilians in the highly centralized staff of OSD had the background and education to carry out the process, eliminating the professional judgment of the military officer. This problem has diminished greatly with the rapid growth in military expertise in the systems approach.

3. Frequently an incomplete or inaccurate methodology was used. Failure to consider qualitative factors led to an overemphasis on quantitative analysis. The desire to use special management science techniques led to shaping the system to fit the analytical tool rather than the reverse.

In a recent article in Strategic Review, Admiral Hanks forecasts a positive future for this systems approach within the Department of Defense. "All of this is not to argue that systems analysis is a development which should be banished from the national security scene. On the contrary, the techniques used in this new method of analysis are useful aids to decision making and should be employed throughout the planning process. But they must not be permitted to drive the endeavor." 10

The Planning, Programming and Budgeting System. While the PPBS is a system itself, it also uses a systems approach to function as the key decision making structure for the Department of Defense. In fact, a primary reason for its implementation was to bring together the isolated activities of the individual services and

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9. Quade and Boucher, p. 2.

10. Adm. Robert J. Hanks, "Whither U. S. Naval Strategy?" Strategic Review, Summer 1982, p. 18.

bring about an integrated, objective oriented Defense program. According to a recent Joint DOD/GAO (Government Accounting Office) Working Group report, the "PPBS continues to be an extensively developed and flexible resource allocation system that supports its decision making. Few, if any, other federal agencies have done as much to systematically set goals and objectives, establish needed fiscal resources, and review the results of their activities." 11

HOW THE SYSTEMS APPROACH CAN ASSIST IN DECISION MAKING

If one adopts the systems approach to decision making, how will it affect the quality of choices made? Certainly in situations where the relationships are simple or time forces a "shoot from the hip" decision, the systems approach makes little sense. However, when the size and complexity of problems reach the proportions frequently seen in the Defense Department, a process for organizing the factors involved and systematically evaluating all of the relevant information becomes invaluable.

The assistance that the systems approach provides to decision making can be described in two ways: first, by outlining its general impact on the overall process: and second, by listing specific ways it can lead to better decisions.

The Three "Faces" of the Systems Approach

Johnson, Kast and Rosenzweig have postulated an excellent model of the systems approach as it applies to the general responsibility of decision making. They suggest that the systems approach is (1) a way of thinking (ie., a systems view), (2) a method or technique of analysis (ie., a decision process) and (3) a managerial style (ie., similar to the PPBS). 12 Thus the systems approach makes a multi-dimensional impact on decisions by setting up a common base of understanding, providing a realistic analytical structure for comparing alternatives and serving as an excellent interface with those management functions that carry out decisions.

Systems Approach as a Philosophy. Given that decision making is ultimately a thought process, the systems approach encourages reasoning which maintains the total system as the focal point so

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11. The Joint DOD/GAO Working Group on PPBS, The Department of Defense's Planning Programming, and Budgeting System (Washington: U.S. Govt. Print. Off., September 1983), Overview.

12. Johnson et al., p. 114-138.

that solutions which improve subsystems at the expense of higher systems will be de-emphasized. All of the attributes of the systems view (wholistic viewpoint, goal oriented, all factors considered, and a dynamic, systematic process) are brought to bear on the decision.

Systems Approach as an Analytical Technique. Any decision making process with the characteristics of the systems view will normally use the systems approach. Both Systems Analysis and the Decision Process fit this description. Thus two systems are involved in this form of decision making; the system which describes the reality where the decision takes place, and the decision process system which provides a systematic methodology for choosing alternatives.

Systems Approach as a Management System. Probably there are few better examples of the use of the systems approach as a management tool than the Planning, Programming and Budgeting System. Its emphases on the whole picture, objective oriented decision making, consideration of all relevant factors, and a systematic process clearly identify a systems approach that has achieved major improvements in deciding how to allocate Defense resources.

The Specific Benefits of a Systems Approach

When one gets down to the "bottom line," the question to be asked is, "Exactly how does this concept help me to make better decisions?" While many advantages have been alluded to throughout this chapter, let us draw together a specific list of ways that the systems approach can help deal with complex problems.

Provides a framework for decision making. The systems approach establishes a process by which a decision can be systematically and reliably analyzed. It will accommodate a much wider variety and more complex set of components and relationships. This systems framework may not always produce the "right" solution but it certainly will lead to improved understanding of the issue.

Organizes the decision situation. The saying that "a problem well stated is half solved" is very much in harmony with the systems approach. Taking the time to describe the system--its components, activities, relationships, inputs and outputs--will be beneficial throughout the decision making activity. Two perspectives should become much clearer with even a simple depiction of the system. The first is the identifying of the parts of the systems and their relationships. But the second perspective of visualizing the overall system and how it fits into the higher system may be far more useful.

Focuses on the Objective. Only by knowing the objective of the system can one rationally choose alternatives. Beware of

identifying the objective of the decision--which is usually to make the best choice. It is the objective to be achieved by the resources being allocated in the decision that is the proper systems approach concept. This objective also serves as an excellent self-correcting mechanism. We will always want to check potential alternatives against it to insure the process is providing proper results.

Clearly recognizes the costs and benefits of a decision. As the costs of a decision are considered the resource inputs to the system, we can openly identify the impact of a given choice. In the same way, the output of the system represents the benefit gained from the use of resources and thus provides a reasonable measure of how well the particular alternative way of operating the system will achieve the objective.

Forces a broader view of the decision. The systems approach forces the decision maker to look at the environment surrounding the system being analyzed by requiring definition of internal and external factors and identifying the higher systems involved. Although the model used in the process may suggest a closed system, the effective systems approach will include the reality of an open system view. Obviously a broader view will include qualitative factors as well as the more specific quantitative data. The use of a model in the systems approach will also permit the use of Management Science techniques that will provide more comprehensive analysis of the quantitative relationships. Finally, the explicit consideration of uncertainty by the systems approach is of great value to decision making. The systems process will identify uncertainty, explore its relationships, define possible parameters and test the range of uncertainty to see its affect on the decision.

Strengthens the communication of decisions made. Certainly if we could get all of the decision makers in any organization thinking and talking the same language, the efficiency of the group would be improved. The use of a systems approach can achieve that goal. Not only does it provide a common terminology, but it is specific and strives to be objective. Having a common perspective of the organization as a system and subsystems, seeing the management process as a series of systems, and transferring to the decision maker the assessment of major decisions in the form of systems analyses is bound to be of considerable advantage to the overall quality of decision making.

SUMMARY

If the goal in decision making is to make the best possible choice, then the concept of a system, the systems view and the systems approach to decision making can make major contributions to

that end. Two changes in personal viewpoint must be made before one can fully utilize the benefits of systems methodology.

The first is to develop a systems view, that is, to restructure one's perception of reality to focus on overall systems as frames of reference. To do this, a basic understanding of the concept of a system is essential. Defined as a set of related parts and activities designed to use resources to achieve an objective, a system inputs resources, performs some transformation process and outputs benefits that are intended to accomplish that goal. While we may wish to use a "closed system" construct for analytical purposes, a more realistic "open system" will lead to more comprehensive decisions by recognizing the affects that the external environment and higher systems have on the system under consideration. The systems view has four characteristics that are advantageous to decision making: a wholistic viewpoint, a goal orientation, consideration of all factors, and a recognition of dynamic, systematic activity.

The second change needed to fully use systems methodology is to employ a systems approach to decision making. This is a very pervasive concept which includes adapting the systems view as a way of thinking, using a systematic process such as the Decision Process to accomplish the analysis of the decision, and employing a management system structure to couple the systems view with the analytical process in order to accomplish established objectives. An excellent summarizing thought on the essential role the systems approach can play is provided by Johnson, Kast and Rosenzweig. "Modern managers must be capable of coping with larger and more complex systems than ever before. Conceptual ability, tolerance for ambiguity, and a sense of the situation are becoming essential for managerial effectiveness. The systems approach fosters the development and refinement of these skills." 13

13. Johnson et al., p. xvi.

CHAPTER III

THE FORMULATION PHASE

The outline in Figure 1 identifies each of the phases of the process and the various elements within the phases. If used in the right way, this outline will be very useful as we develop the process. It is intended to serve as a roadmap, a guide to tell where we are and what is yet to come. It illustrates how the phases of the Decision Process work together to support effective decision making. This diagram should not be used as a checklist or template, something to be placed against a pending decision with the expectation that the right answer will be produced automatically.

Remember that the different phases do not stand alone. They are interrelated, with each contributing to the final form the other will take. The initial formulation may require significant changes as we work through the process and learn more and more about the decision to be made. Moreover, the elements within each phase tie together in various ways. They have an impact both upon other elements within the same phase and the elements in different phases. As proficiency grows in using the Decision Process, so will the ability to consider several elements simultaneously rather than sequentially. For these reasons we emphasize the box near the left side of the outline which has the words "AN ITERATIVE PROCESS." Never expect to routinely proceed down the outline from element to element as we are going to do in this chapter. The Decision Process is a dynamic methodology with a lot of feedback and iteration. The intention is to capture the essence of a thought process. So let's begin!

The Formulation Phase provides an excellent format for beginning the process of decision making. It is based on the premise that, before one goes chasing after possible solutions, it is necessary to understand what is the real decision to be made, what are the right questions to be asked and which of the many factors involved in the situation will affect the outcome. The contribution that formulation makes to the Decision Process cannot be overemphasized. While all phases contribute to the success of the process, the intensity and excellence of effort put forth during the Formulation Phase are significant determinants of the overall quality of the decision.

An interesting perspective on the role of formulation is the change in focus that begins during this phase. The decisions most appropriate for using the Decision Process are those which are very broad and complex, with many quantifiable aspects as well as factors which require subjective judgment. It is the Formulation Phase that

THE DECISION PROCESS

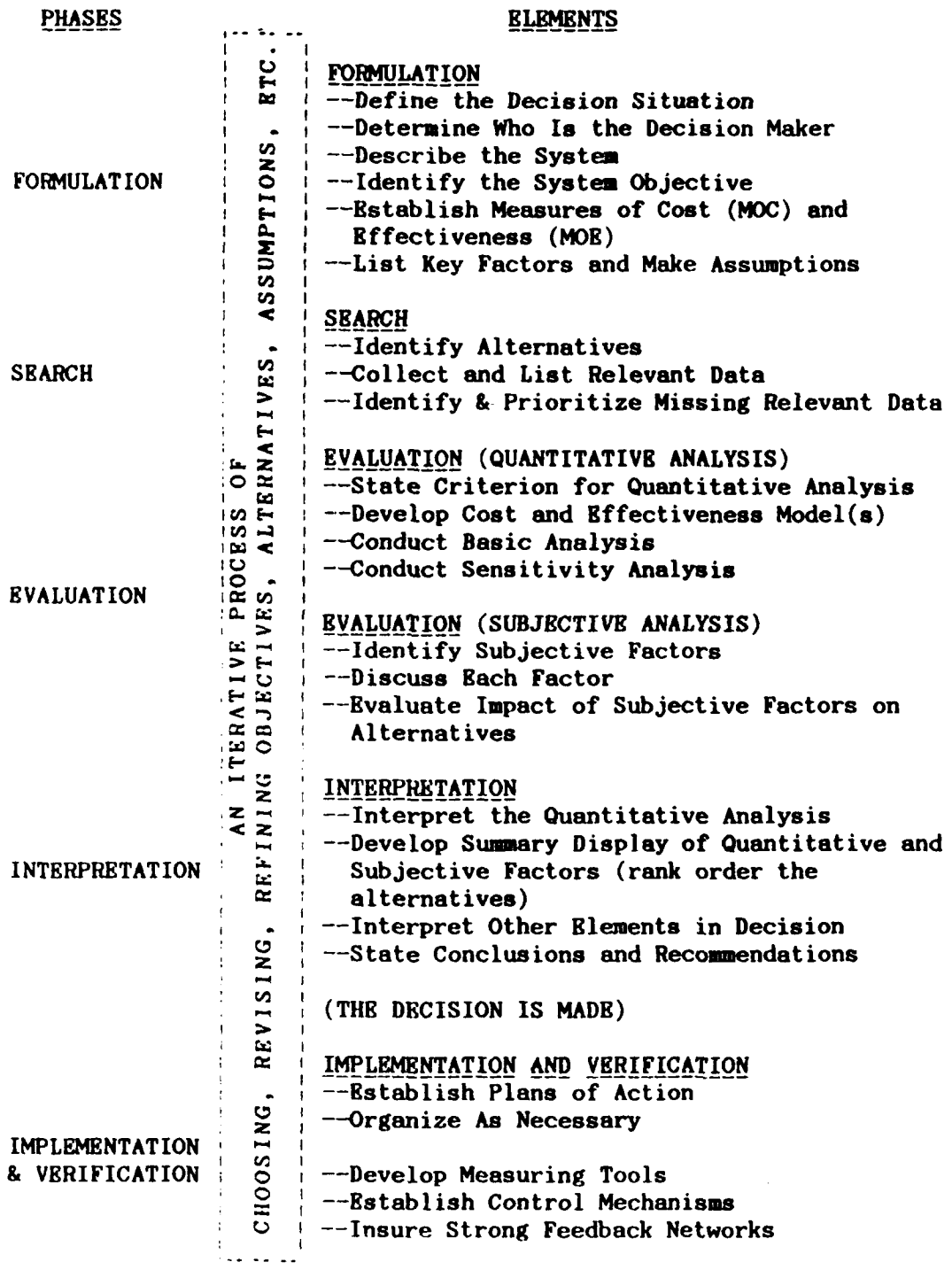

Figure 1: The Phases and Elements of the Decision Process

begins to narrow the attention of the decision maker to the essential facts of the decision. Later we will learn that the Search Phase separates out irrelevant information and factors not directly involved. At the "narrowest" point in the process, the evaluation of quantitative relationships takes place. Then the focus of the Decision Process broadens again to encompass less tangible factors and the total environment in which the decision maker must make his choice. Figure 2 illustrates this perception of the Decision Process and the initiating function of the Formulation Phase.

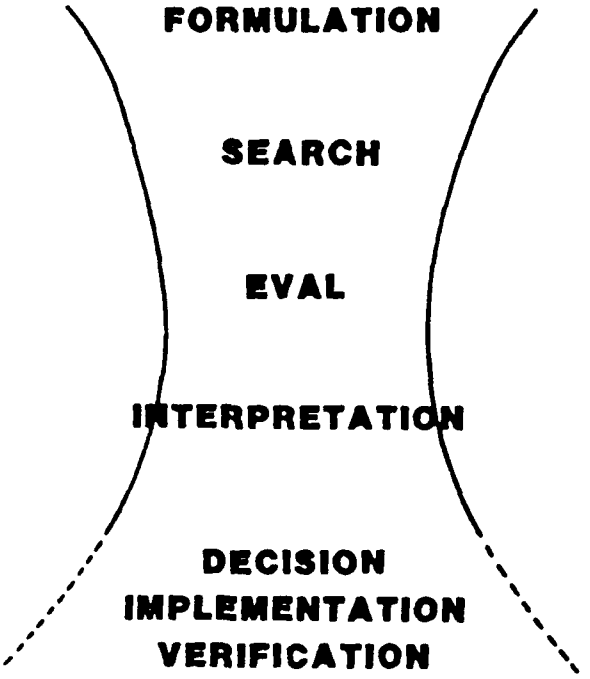

Figure 2: A perspective of the Decision Process

Finally, the Formulation Phase serves as an initial communications tool as well as a spark plug for the overall process. Several individuals working with an identical set of information may communicate differences on the details of formulation. However, if they agree in principle with the initial conceptualization of the issues, their efforts should lead to very similar conclusions. And, if they do disagree on fundamental issues, these differences can be resolved early in the process, or at least be recognized at the onset rather than degenerating into an argument over results. Formulation also serves as the phase that transforms the entire

Decision Process from a static framework to a dynamic process. It is only when the decision situation has been identified, when objectives have been more clearly defined, and when the ability to measure the benefit and cost of alternatives has been developed that the actual process of decision making can begin.

ELEMENTS OF THE FORMULATION PHASE

As indicated in the outline of the Decision Process, the Formulation Phase has six elements: Decision Situation, Decision Maker, System, System Objective, Measures of Effectiveness/Cost and Key Factors/Assumptions. We will consider each in turn.

Define the Decision Situation

In the same manner that the Formulation Phase initiates the Decision Process, to define the Decision Situation is the natural starting point for this phase. Just what does the term mean?

> A DECISION SITUATION IS A CONDITION WHICH REQUIRES A RESOURCE ALLOCATION DECISION TO CLOSE THE GAP BETWEEN THE CURRENT SITUATION AND A DESIRED GOAL.

The current situation being identified in the decision situation may be a requirement that has just been identified or one that remains unfilled due to limited resources. It may be an opportunity for improvement. The gap is the difference between the current situation and what could be achieved.

Once the decision situation is recognized, it is time for a procedural decision to be made. Is the situation worth a detailed application of the Decision Process or not? There is little justification for wasting time in pursuit of either an trivial effort or an impossible choice among alternatives. Some choices raise the topic of whether or not a decision is possible. There must be feasible alternatives that achieve the goal before we continue in the attempt to find a final solution.

In what kind of format should the decision situation be written? While no specific style is necessary, a good approach is to first describe the current situation, particularly if it is felt that something is wrong. Then briefly state what outcome the resources are to achieve. This identifies the "gap" that signals a decision situation. It should be written as briefly and as precisely as possible. If an extensive background discussion is really necessary to describe present conditions, try to end with a short, concise statement of both the current situation and the goal that resources are to achieve.

Determine Who Is the Decision Maker

Control is a powerful word. In identifying the decision maker for choices involving resource allocation, look for control, not execution.

> THE DECISION MAKER IS THE INDIVIDUAL WHO HAS RESPONSIBILITY FOR DECIDING HOW THE RESOURCES INVOLVED IN THE DECISION ARE TO BE USED.

Implicit in this definition is the idea that the decision maker is able to exercise control over the resources to be allocated and, because of his assigned mission, is very interested in their effective use. Of course the "decider" realizes that both the environment and his seniors in the chain of command can exert influence on his actions, but when we identify the decision maker it is to locate the intended point of responsibility.

Why identify this individual? Consider two reasons. First of all, the entire Decision Process should be developed from the viewpoint of the decision maker. The environment, key factors, constraints and assumptions all must reflect the perception held by the individual responsible for the choice. One can be sure that when the results of the process are reviewed by the decision maker, all of the realities that actually do exist in his or her environment will be intuitively considered before making the decision. Placing a boundary around the objectives and alternatives to be considered is a second reason for identifying the decision maker. This person's area of assigned responsibility defines the resources available and the objectives to be accomplished. Therefore, if alternatives are proposed which call for additional resources or adjustments in the mission, then it is important to know that those changes must come from a decision maker at a higher level before they can be included in the Decision Process.

Describe the System

Once the decision situation and decision maker have been identified, the next step is to describe the system in which the choice is being made.

> A SYSTEM IS A SET OF RELATED PARTS AND ACTIVITIES DESIGNED TO USE RESOURCES TO ACHIEVE AN OBJECTIVE.

A system has individual parts called components or elements which have predetermined relationships with each other. All systems have resources flowing into them as inputs. They process these resources by the interaction of the components in the system and produce an output which hopefully will achieve the objective. Each system is a part of a larger system and is affected by it and other external systems. Thus, the main reasons for identifying the system involved in a decision is to define alternatives and evaluate how well each

of the choices would "operate" in the system to accomplish the objective.

There are other ways in which describing the system will help to carry out the Decision Process. Accurate system definition is essential for the next part of the Formulation Phase, the identification of the system objective. There is a risk involved in describing a system, especially an existing one, before determining the objective of the system. The analysis may unintentionally exclude viable ways to accomplish the desired goal, and result in an allocation of resources to a less productive effort. Identifying the system is a very good way to get a feel for the general structure of the decision. It is then equally important to focus on the system objective, the next part of formulation, before finalizing the system description.

Identify the System Objective

Making sure that the system objective is clearly identified is the most important outcome of the Formulation Phase. In fact, at times the primary reason for using the Decision Process is to identify the objective that the system is intended to achieve.

THE SYSTEM OBJECTIVE IS THE DESIRED GOAL THAT THE OUTPUT OF THE SYSTEM IS EXPECTED TO ACHIEVE.

The system objective serves as the overall guide for choosing among alternatives. While we will shortly develop special procedures for comparing the benefits and costs of alternatives, the stated goal still remains the final determinant of which choice is best. The system objective can also be used as a screening device to eliminate alternatives that are not feasible because they do not meet the goal. Identifying the objective may be a natural by-product of describing the system, probably because of the natural tendency toward goal-oriented behavior in day-to-day activity. In fact, we could easily identify the objective first and then describe the system that produces it.

Several key points can be made about a system objective. First of all, it is output oriented, closely related to if not exactly the same output that the system produces. Secondly, the objective emphasizes what a system should produce, not how. How it achieves this system objective is determined by which alternative is chosen. Thirdly, most objectives tend to be stated in such very general or abstract terms as: "deter," "defend," or "operate effectively." Every effort should be made to be as specific as possible, trying to use words which suggest ways to measure output as well as defining the objective. Fourthly, complex systems frequently have multiple objectives--more than one goal to be accomplished by the resources. Because solving problems in

systems with more than one goal makes the decision process far more difficult, always try to focus on just one objective. The problem of multiple objectives in a decision is frequently resolved in one of two ways. The goals can be prioritized, focusing on the most important one first and assessing the impact of other objectives later in the analysis. The other approach is to attempt to define a "collective objective," a redefined objective which tries to consolidate all of the goals into one.

One final point: the objective of a system should support the objective of the higher system that encompasses it. When viewed from the higher system, sub-system objectives tend to become more specific and more narrowly focused on the particular task to be achieved. The effort to optimize this more narrow sub-system objective without due regard for how it affects the achievement of higher system objectives is called sub-optimization. One should be cautious about optimizing the sub-system when it affects the successful attainment of higher system objectives.

Establish Measures of Cost and Effectiveness

The requirement exists for a measuring tool which will be used later in the Decision Process. We will want to use two "yardsticks," one to measure how effectively each alternative meets the system objective and one to measure how much each alternative will cost in terms of resources used. For the first task we must decide which quality we should measure to determine the effectiveness of each alternative. We then develop a measuring scale called the Measure of Effectiveness (MOE) which is calibrated in units of this quality. For the latter task we must determine which quality we can measure which best indicates the cost of each alternative. This measuring scale is called the Measure of Cost (MOC) and will also be calibrated in units of the quality best representing resources used. Even though the MOE and the MOC are not used until later in the Decision Process, we discuss both of these concepts now because of their close relationship to the system objective and because we need to know what qualities we plan to measure before beginning the Search Phase. Let's discuss each one.

The Measure of Effectiveness (MOE). Effectiveness is the term used to describe the productive output of a system. It is the benefit one hopes to derive from expending resources. Each alternative produces some level of effectiveness and we use the MOE to determine that quantity.

> THE MEASURE OF EFFECTIVENESS IS A SCALE USED TO DETERMINE THE QUANTITATIVE EFFECTIVENESS OF AN ALTERNATIVE. THE QUALITY MOST REPRESENTATIVE OF EFFECTIVENESS IS USED AS THE UNIT OF MEASUREMENT.

A definitive statement of the system objective should suggest a quality which we can use to measure the effectiveness of

alternatives. The label or unit of measurement should be one that all understand.

Picking the good MOE is sometimes a difficult task. Frequently, there is not a specific quality that has close identity with the objective, one that provides a realistic indicator of success. At times there is no attribute that clearly represents achieving the objective, or obtaining the needed information is cost or time prohibitive. For these cases we must revert to a proxy or surrogate type of measure of effectiveness. This proxy measure is some attribute of system output that is measurable and has reasonably high correlation with successfully meeting the goal.

Even more challenging is the situation where more than one Measure of Effectiveness is needed to evaluate how well the choices meet the objective. Suppose that there are five critical attributes (five MOEs) that affect the selection of a main battle tank. How are the differences in effectiveness evaluated for the various alternatives? Typically each alternative has certain MOEs where it rates high in effectiveness, but other MOEs where its effectiveness ranks considerably below the other alternatives. The result is a matrix of effectiveness ratings for the various alternatives, none of which appears to be the best choice. When forced to use multiple MOEs, try to reduce the difficulty this can cause in one of the following ways. Look first for an alternative that ranks highest in all of the measures of effectiveness. This is certainly the easiest solution. If there is no dominant alternative, attempt to develop a proxy MOE that will represent the several MOEs in some composite form. One final way to deal with multiple MOEs is to use a "wicket" approach. Required levels of performance are established for each of the Measures of Effectiveness. Alternatives that meet all of these required levels of MOEs are considered equal in effectiveness. The importance of any effectiveness exceeding the required level is considered later in the Decision Process.

Measure of Cost (MOC). The costs of selecting a particular alternative are the resources to be consumed or the opportunities to be foregone by the choice of that alternative. Because there are so many ways that cost can be expressed, all of Chapter IX is devoted to the subject. To quantitatively evaluate the cost of alternatives, a Measure of Cost yardstick is developed which will specify what kind of cost we are going to measure.

> A MEASURE OF COST IS A SCALE USED TO DETERMINE HOW MANY RESOURCES ARE EXPENDED BY CHOOSING AN ALTERNATIVE. THE QUALITY MOST REPRESENTATIVE OF THE RESOURCE COST IS USED AS THE UNIT OF MEASUREMENT.

It is surprising the amount of confusion that is generated by the word "cost." Most people automatically think of money when cost is mentioned. Dollars are a very useful way to measure cost, because

the worth of many resources can be converted into monetary terms. Because meaningful comparison requires that the measuring scale be common to all alternatives, we again tend to turn to dollars as the MOC. On the other hand, there are many situations when dollars are inappropriate as a measure of cost. In decisions involving actual physical resources, the dollar cost of the resources may be relatively unimportant. The number of aircraft scheduled to fly close air support missions may be a far better MOC in a tactical decision than the monetary cost of the aircraft. Fuel and ordnance that are consumed today and not available for use tomorrow may be a far more realistic measure of the cost of a decision than the dollar value of these consumables. Time is also a critical resource that may appropriately be used as the MOC in many decisions.

Listing Key Factors and Making Assumptions

To this point in the Formulation Phase, the emphasis has centered around the effort to describe the decision situation, the objective to be achieved, and ways to measure the cost and effectiveness of alternatives. Many critical factors which shape the way the decision will be made, or shape the Decision Process itself, remain to be identified and structured. To keep from overlooking these key factors and assumptions, we undertake the final step in the Formulation Phase: listing them for future reference. Let's start with a definition of key factors.

> KEY FACTORS ARE THOSE ITEMS OF INFORMATION WHICH MAY INFLUENCE THE DECISION, OR THE PROCESS OF MAKING IT.

Listing the key factors in a decision is a convenient way to identify and bring together all the information which may have relevance to the decision and, because of the complexity of the decision, might be overlooked unless special note is made of them. While these factors come in all shapes and sizes, they can be categorized into a few general groups.

o Key Information: Essential factors that clearly affect the choice of alternatives. For example: all costs are in current dollars; two of the contractors have extensive experience; the local population is very pro-military.

o Constraints: those key factors that set specific limits on such things as resources, alternatives and objectives. Examples would include: a maximum budget level; consider no alternative that uses foreign equipment; no collateral damage when targets are destroyed.

o Constants: those factors that remain the same regardless of the alternative selected. For example: telephone lines available.

o Factors affecting the analytical process itself: those factors which provide guidance on the analytical effort. For example: consider only readily available data.

Whether a factor is "key" or not is strictly a matter of judgment. The prime determinant is the probable influence of that factor on the eventual preference for alternatives or the accuracy of the decision process. Reasonable advice is to start somewhat conservatively by listing factors of questionable influence and then eliminating the non-relevant ones as the Decision Process is completed. The procedure for drawing up this list of key factors is also strictly a matter of personal convenience.

Making assumptions is the second part of this final step in formulation.

MAKING ASSUMPTIONS IS THE ACT OF STATING UNCERTAIN OR UNKNOWN INFORMATION AS FACTS SO THAT THEY CAN BE USED IN THE DECISION PROCESS.

Uncertainty is a fact of life in complex decisions, but also a factor which the Decision Process handles especially well. When making assumptions there are several things to keep in mind. They should be made explicitly so that the underlying premises are clearly understood. It is good practice to list them at this particular point in the Decision Process so that everyone involved in the effort will start with the same set of assumptions. At some point later in the Decision Process, assumptions should be re-visited to determine what effect a change in those assumptions would have on the preference for alternatives. This procedure is called Sensitivity Analysis and is discussed at length in the Evaluation Phase.

Assumptions can be the strength or the Achilles Heel of the Decision Process. So often, when a study which has used a formal analytical process is being attacked, it is the assumptions that receive the brunt of the pressure. On the other hand, being explicit about assumptions, insuring that they are well thought out and testing their sensitivity to a change will result in a far more objective and defendable analysis on which to base the decision.

One final footnote about listing key factors and making assumptions. While they both involve relatively important information, they do not represent all relevant data. To the contrary, it is one of the purposes of the subsequent Search Phase to seek out the detailed information upon which the alternatives will be evaluated. Having three potential locations for data causes many to worry about whether a piece of information is a key factor, an assumption or data for the Search Phase. Where each piece of information goes is far less important than ensuring that all relevant factors are identified and used in the overall process.

SUMMARY

Getting started is hard to do, especially if one wants to head in the right direction. The importance of the Formulation Phase in conceptualizing and organizing all major aspects of the decision to be made should not be underestimated. Taking the time to carefully define the decision situation will insure that the right problem is analyzed. Many of the activities that enable a good decision to be made flow from the effort to describe both the system involved in the decision and its objective. Measures of Cost and Effectiveness will be of great help in deciding what data to look for in the Search Phase, and they will be essential for the evaluation of alternatives. Finally, beginning to list the key factors and making assumptions will permit the overall process to proceed in a far more organized and effective manner.

CHAPTER IV

THE SEARCH PHASE

The focus of the Formulation Phase was finding the objective; the central issue in the Search Phase is developing alternatives that will achieve that objective. This phase is a research process as well as a method for finding alternatives. The intent is to look for information and relationships that will help to define clearly the various courses of action. We are particularly interested in the effectiveness and cost of each alternative. This will be the primary basis upon which we will quantitatively evaluate the choices. "Creative" is probably the most appropriate word to describe the mind set needed during this part of the Decision Process. This attribute is not only essential for proposing unique alternatives, but is also valuable in the research effort.

The search effort can rarely be isolated from other phases in the Decision Process. It is very likely that as soon as we start to define the decision situation and identify the objective during the Formulation Phase, we also begin to think of ways to reach that desired goal. In a similar way, once we begin to compare the courses of action in the Evaluation Phase, it is likely that new alternatives and additional data requirements will come to mind. Therefore, it is not expected that the phase we are about to describe will be carried out after you finish formulating the decision and before evaluation of alternatives begins. The Search Phase will reach into all other phases of the Decision Process because the search for data is a never ending process. Alternatives are never fully evolved until their implementation is complete.

Figure 1 shows the three activities of the Search Phase. This chapter will develop the conceptual basis for these elements.

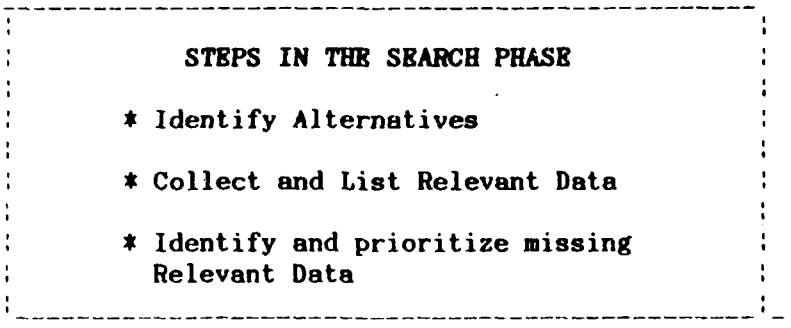

Figure 1: The activities of the Search Phase

FINDING ALTERNATIVES

What exactly are "alternatives" and where might they come from? The answers to these two questions and some guidelines for developing a reasonable list of alternatives will provide an excellent introduction to a discussion of the research effort itself.

Choice, option, course of action, solution, and proposition are all terms synonymous with the word alternative. While most people are fully aware of the general meaning, we offer the following specific definition:

> AN ALTERNATIVE IS A SET OF ACTIVITIES, WITH DEFINED VALUES AND RELATIONSHIPS, WHICH MAY BE SELECTED BY THE DECISION MAKER TO ACHIEVE OBJECTIVES.

Alternatives are different ways for the decision maker to use resources to achieve objectives. Using the terminology of the Decision Process, alternatives are sought to close the gap between the current situation and the system objective that was identified in the decision situation. Defined from a systems viewpoint, alternatives represent different possible ways that the system in question can be operated to achieve its goals. The diversity of possible alternatives is often limited only by how much creative effort has been applied.

Where Alternatives May Be Found

In most cases, the awareness of a decision and alternative courses of action come to mind at the same time. In fact, it could be said that alternatives often seek out the decision maker rather than the other way around. It is very important that these ideas are not discarded or evaluated too soon. In the initial stages of a decision, the task is to bring forward as many feasible alternatives as can be handled, and to avoid exercising quick judgment as to how well they will meet the objective. This approach is frequently called brainstorming, the effort to suggest new options without immediately applying judgment as to how good the idea is. In the interest of developing all reasonable options, every area where alternatives may be found should be explored.

The Status Quo. Often overlooked in the search for alternatives is the option of not doing anything--letting things continue as they are currently operating. Of course, this applies only to choices in systems that are already functioning and not to decisions involving new acquisitions or operations. Frequently the status quo is producing effectiveness that is not clearly evident until it is replaced by another course of action. An alternative that is in place and working may have many unseen advantages over

one that requires a lot of effort to be carried out. But the very existence of a gap in the decision situation usually means that the status quo is not achieving the objective, and a search for better alternatives should be made. In many cases, an opportunity surfaces in the form of a new alternative to an otherwise satisfying status quo. The current way of doing things can then become a potential drawback to a better use of resources. Even though not perceived as fully effective, the status quo should be considered as an alternative, if for no other reason than to serve as a baseline against which to compare other choices.

Decision Maker's Guidance. Frequently, a decision is required because the decision maker is faced with a clearly defined set of choices. He may communicate these alternatives, with or without bias and supporting information, to a subordinate who is to evaluate the courses of action. This form of guidance on what alternatives to consider is often identified in the decision situation. Experience has shown that it is usually helpful to look beyond these given alternatives to more creative choices. This will make full use of the methodology of the Decision Process and increase the chances that the best use of resources will be achieved. This is not to say that analysis limited to alternatives given by the decision maker can't be an honest and objective one, but only that the results may be more of a satisficing than an optimizing solution.

The Decision Process Itself. As a methodology the Decision Process will generate new alternatives as well as evaluate and rank order existing options. This is especially true when the choices to be evaluated do not appear to solve the problem. There are many steps in the process with the potential for identifying new courses of action. The development of a systems view will cause one to identify the various activities and relationships that define possible alternatives. Defining the MOE and MOC requires insight into how various courses of action might produce effectiveness and incur cost. Of course, the entire Search Phase is aimed at identifying alternatives. In the Evaluation Phase model development and the evaluation of both quantitative and subjective factors will suggest adjustments to existing choices as well as totally new options. Finally, the ever-present iterative process will be a continuous source of new alternative by causing revision and adjustment to previous results of the analysis. We say that the Decision Process is one which explores the full problem, illuminates objectives and examines all alternatives. Implicit in this definition is the requirement to develop new alternatives if those examined are found lacking.

Seek Expert Advice. In areas of defense decision making, there are usually experts who are able to suggest a broad range of reasonable alternatives. Government laboratories, for example, are a built-in source of ideas. Defense contractors are especially

eager to suggest new alternatives in the form of responses to Requests for Proposals. Alternatives may also be found by asking other experienced military sources, such as the personnel working in the development, logistics, and operational commands. Even looking outside the defense environment to industrial and domestic activities can be very fruitful, often providing the most creative options for consideration.

The above list is only a few of the possible sources for a well developed set of alternatives. Obviously, the amount of effort expended will depend on the complexity of the decision and the need for creative approaches to its solution. While having too many choices may make the decision process more difficult, having too few options may negatively affect the decision itself. It is better to eliminate alternatives later in the process than to overlook the unique one that makes a real breakthrough in the effective use of resources.

Guidelines for Developing Alternatives

There is no exact formula or school solution for insuring that one has the right combination of alternatives. Trying to insure that all possible areas have been searched and the creative effort has been exhausted is probably the best test of completeness. Of course, the iterative nature of the Decision Process is very helpful as it continually leads to reconsideration of steps that uncover new courses of action. Here are some guidelines that can be useful when developing a list of choices that will lead to a good decision.

Keep the Number Manageable. One cannot possibly consider every possible alternative that might be considered in a decision. While one may initially generate a very long list of possible choices, action must be taken to limit the number to be evaluated. This can be done in several ways. Several alternatives can be combined into one choice that represents a common set of attributes. Another technique is to simplify or reduce the variables being considered to those that incur a sizable commitment of resources. One suggestion for establishing a rational boundary on the number of alternatives is to make a preliminary screening of choices, arbitrarily ruling out marginally feasible solutions. These temporarily discarded options can be easily compared to the evaluated alternatives later in the process.

Be Creative. Developing alternatives should be a creative process. The value of new ideas and new approaches for achieving the objective can not be overemphasized. There are strong organizational and bureaucratic pressures that resist this particular guideline. The Decision Process requires the decision maker to think in terms of the resources that are used in the system, the activities and relationships that transform those resources and the ways in which the productive output of this effort

can meet the objective. Each of these elements of the system offers ways in which new alternatives can be formed and revised.

Alternatives Must be Feasible. How many times are we led astray by the great idea that doesn't work? We should only consider alternatives that are capable of being carried out. At what point in the Decision Process we eliminate the infeasible alternative is highly dependent on what factor caused it to be unsuitable. If the course of action cannot meet the objective, then it should be dropped as soon as that shortcoming is realized. However, if the alternative is not feasible because of a constraint that has been established, then that option should be retained until it is determined that the constraint cannot be changed.

Be Explicit When Eliminating Alternatives. Fully documenting the reason for excluding an alternative is vital to the communicative strength of the Decision Process. This is especially true if you are using the Decision Process to provide advice, or as a structure for analysis. In these cases the absence of a viable alternative, even though discarded for good reason, will raise questions if not fully explained. Don't assume a decision maker knows why you did not consider the obvious options.

Be Sensitive to the Chain of Command. If there are several levels of management between the individual using the Decision Process and the decision maker, then the choice of alternatives should be sensitive to what those in the chain of command might expect to see considered. Doing this must not compromise the objectivity of the Decision Process. However, answering questions in advance may reduce the resistance to the analysis reaching the decision maker. This is especially true of DoD weapon system procurement choices which get a lot of attention as they pass through the chain of command.

A Final Note on Alternatives

It can be truthfully said that identifying options is more like a creative activity than a mechanical process. Although the goal of the Decision Process is to be objective when evaluating alternatives, the personal qualities of initiative and innovation are essential for the task of identifying the choices to be considered. Indeed, there is no systematic procedure to insure that all the viable alternatives are listed. Coming up with good choices is a challenge that requires an imaginative approach combined with an exhaustive effort.

COLLECTING RELEVANT DATA

The second element in the Search Phase involves seeking, gathering and displaying the information necessary to evaluate

alternatives. This part of the chapter offers insight into the categories and sources of this data that are essential to the Decision Process. We shall first discuss some general characteristics of the data collection effort and then outline several practical suggestions for carrying out the search procedure.

The Data Search in General

The Challenge. The world of research has changed a lot in the past twenty years. That change is especially noticeable in the manner which the search for data must be carried out today. When the term Search Phase was introduced by E. S. Quade in 1968 to describe a systematic research effort, the difficulty faced was where to find the data. The challenge was to ferret out from operational practice and past experience the facts needed to compare alternatives. Most information was manually recorded, haphazardly stored, or not kept at all. Today, more often than not, an entirely different problem is faced in the Search Phase. The explosive spread of data processing equipment and management information systems has created a situation where there is too much data.

What's Relevant? Relevancy is a very critical sorting tool in the Decision Process. Without it, the process quickly gets mired in the glut of extraneous information that can completely mask the decisive factors in a Defense issue.

> RELEVANT DATA ARE THOSE FACTS AND INFORMATION THAT ARE PERTINENT TO THE DECISION BECAUSE THEY WILL SERVE TO DISTINGUISH AMONG ALTERNATIVES AND ARE WITHIN THE PURVIEW OF THE DECISION MAKER.

There are two important concepts included in this definition. The first concept underscores the importance of relevant data in simplifying the comparison of alternatives. We are looking for data that differentiates between the various courses of action. To choose between alternatives we should try to screen out data having the same value for all choices. For example, you are tasked to select desktop computers for use in the Pentagon. All of the computer systems under consideration have 128 kilobytes of built in user memory. If that capacity meets the desired objective, this data point will not affect the choice of computers. To include it in the data display will only serve to obscure other information that is different from alternative to alternative. This is not to imply that information common to all choices is not used in making the decision. All data included in the total effectiveness or cost of an alternative will certainly be relevent when determining whether that choice does or does not meet the objective. The point is that, as we subsequently evaluate alternatives, the focus will be on those factors which differentiate among the courses of action. The data collection effort must provide this kind of information.

The second concept to be emphasized in the definition of relevant data is the research boundary. We should limit our search for data to those areas which are within the purview of the decision maker. This means that we want to look beyond the immediate system to its environment, but not try to capture the entire world. If we do not set a research boundary, we may omit very significant external factors by not looking far enough away from the immediate problem. Without a boundary we also may quickly lose sight of where to stop our research effort and bury the relevant data in a mountain of useless information.
power use in the decision.

There are two basic categories of relevant data. The first is information which will assist in measuring the effectiveness of alternatives and the second category is data used to define the cost of resources consumed by each option. The majority of research should be directed at gathering information in these two areas.

Effectiveness data generally include such performance figures as size, speed, payloads, numbers of operating systems, maintenance and operational reliability rates, mean time between failure rates, accuracy, distance and the many other ways that the output of a system can be measured. Often this data is grouped into a composite value which represents several effectiveness data points. For instance, "ton miles per day" is a composite of payload X distance X speed X hours.

There are two requirements of the Decision Process that cause us to search for effectiveness data. The first is the need to clearly define the operating process of the system in which the decision is to be made. Later, during the Evaluation Phase we will use this detailed description of the system to develop a model which can measure the performance of each option.

The Measure of Effectiveness established in the Formulation Phase is the other reason for collecting this category of data. We will use effectiveness information to measure the output of the system. As we operate the system with each alternative being evaluated, the performance values we have included in the Measure of Effectiveness will enable us to determine how much benefit is being produced by that course of action. These data will be compared to determine the choice preferred. This critical role in the ranking of alternatives relies totally on the ability to find relevant and usable effectiveness data.

Cost data have the same importance to the Decision Process but obtaining it is usually less difficult than finding effectiveness data. This is because the cost of a decision is determined by measuring the quantity of resources used. Given that resource accountability is a normal requirement in all organizations, records can usually be found that provide the

relevant data. However, there are two aspects of the concept of cost that do present challenges in the search for this category of information. Cost in a decision is often measured by other than the dollar value. Because of this, the search for cost data must be based on the Measure of Cost established in formulation rather than automatically looking for the monetary cost of alternatives. The MOC may be units of equipment, number of weapons expended, ships lost, or time expended. That measure must guide the research effort. If that type of information is not available or cannot be generated, then the process must iterate back to the Formulation Phase so that a new MOC can be selected.

Never Perfect Information. Obviously, the quality of the data obtained during the Search Phase will determine the accuracy and reliability of the Evaluation Phase as well as the entire Decision Process. The old computer adage would never be more true: "garbage in, garbage out." Hoping to gather complete and totally reliable information is a dream that will never come true. Some information just doesn't exist. Other relevant data may be obtainable, but at a cost far beyond its value. The Decision Process is designed to compensate for this anticipated shortfall by making assumptions and identifying and rank ordering missing relevant data. As discussed in the Formulation Phase, making assumptions allow us to carry out our thought process in the face of uncertainty by stating unknown information as fact. Later during Sensitivity Analysis we test the effect on alternatives of a change in the value of this assumed information. Missing data procedures, which will be introduced shortly, also provide a way to handle imperfect information so that it will not severely handicap the overall Decision Process.

Tips for Collecting Data

The following are some guidelines that should assist in the search for relevant data. They are focused on the Decision Process and should go hand-in-hand with procedures described in technical guides to research activities.

Formulation is the Key. In any analytical process one of the greatest temptations is to dive right into the work of collecting data. Perhaps it is the same fascination with searching that was suggested at the beginning of the chapter. This inclination should be resisted. Although the Search Phase serves as a bridge between Formulation and Evaluation, it must have a firm foundation in the first phase before it can provide a basis for the other. Even though all three phases may happen almost simultaneously in our minds when dealing with a fairly simple decision, this is not the case for complex problems. The Formulation Phase must first provide the guidance for the information needs which are then satisfied in Search.

Many research requirements are established when formulating the decision. To clearly understand the objective may be a major research task all by itself. Description of the system may need more information so that the various activities and relationships in that system can be defined in more detail. Recall that the environment surrounding the system may influence the choice of alternatives. Data collection is needed in order to focus on these "externalities" that are relevant to the decision. Selecting measuring scales (MOE and MOC) to be used to determine the effectiveness and cost of alternatives is a major basis for research. Finally, both identifying key factors and making assumptions generate data collection requirements for the Search Phase. For all of these reasons, formulation serves as a critical preliminary to the task of collecting data.

Group the Data by Measurability. Lack of a common measure of output is a long standing management problem in any non-profit organization. This truism continues to challenge military decision makers. For example, how could you compare the relative contribution of Navy ships and Army tanks in a conventional war scenario? Is it impossible? If not, at least it is very difficult. We can expect to deal with many different measures of performance and output when we are evaluating the complex issues in our national security environment. Likewise, only a part of the total cost involved in defense decisions can be measured in dollar terms. Indeed, dollars themselves are only a surrogate measure for other opportunities given up. Given that the Decision Process is designed to evaluate alternatives based on all types of information, there is one thing that can be done in the Search Phase to help resolve the problem of measurability. If the data can be grouped by their ability to be measured by a common scale, this will prove very helpful in the subsequent Evaluation Phase.

Displaying the Relevant Data

Having discussed several aspects of collecting relevant data, let us conclude this section by suggesting how data might be displayed. The first and probably most important piece of advice is to make the display of data, borrowing some computer terminology, "user friendly." The format should minimize the effort both to document the collected information and retrieve the data from the display. The second suggestion is to organize the format for documenting before starting to collect information. There is nothing more frustrating than to get partially into the listing of data and then realize that there is not enough space to include all of the factors or consider all of the alternatives that have been identified. A matrix structure seems to be the most functional display when there are several courses of action to consider and each one has many variables to record. Attempt to group similar types of data together so that it is easy to spot differences between alternatives that are important for deciding. Be willing to

discard data that does not appear relevant. If time is limited, be cautious about spending an inordinate amount of that time preparing a very neat, highly organized data display. Remember that, although the search for data is a very necessary part of the Decision Process, it is in the Evaluation and Interpretation Phases that the actual evaluating and rank ordering of alternatives will occur.

IDENTIFY AND RANK ORDER MISSING RELEVANT DATA

Because the Decision Process is particularly well suited for large, complex decisions which usually involve considerable uncertainty, seldom will it be possible to collect all of the information needed. Eventually the problem of missing data will have to be faced. There are several reasons why this situation might occur. Perhaps we just don't know the information. It is either an unknown factor or there is so much uncertainty about the values as to make any existing data completely unreliable. Often the information has never been assembled or was collected but not retained. The financial expense of gathering facts or the lack of sufficient time may be the cause of missing data. For whatever reason, steps must be taken to deal with this shortfall so that the process of decision making can move ahead.

How one knows what items are missing may sound like the familiar rollcall ploy, "Will anyone not here please speak up." What clues do we have about what relevant information is missing? One of the obvious indicators, if the data display has been well laid out, is to note where the blank spaces are. Of course, the data will be missed if it is part of a computation or composite MOE or MOC. But the most frequent way that we discover the need for additional data is through the creative effort of the search itself. Usually, the identification of missing data really becomes effective by asking the question, "What do I really need to know to solve this problem?" It is for this reason that identifying missing data is an explicit part of the Search Phase. A three step approach is suggested.

Identify What Data Is Missing. Identifying missing data can best be done by making a brief notation each time information is not available. The research effort will continually fill in portions of this missing data but, at the same time, also suggest new areas where additional data would improve the quality of the decision.

Prioritize Missing Data. The essential nature of data is a matter of degree. Information that is critical to making the decision goes to the top of the missing data list while "nice to have" data goes to the bottom. This will help focus your research

effort on the search for data which must be found before the alternatives can be fully evaluated.

When Missing Data Are Not Found. If the information that cannot be found is in the "nice to have" category, then the impact on the overall process is not too serious. Estimates by experts, data from similar situations or additional assumptions can fill in the gaps in the data base. Many statistical tools are also available to make the substitute information more useful. However, if missing information is crucial to the decision, then major adjustment in the results of the Decision Process must be made. Objectives may need to be revised, key alternatives might have to be dropped, or a major change made in the way that alternatives are going to be evaluated. Once again, iteration plays a major role in adjusting to the unique nature of the decision. It may mean that the entire process must be repeated. But with the knowledge of the missing data, the decision can be structured to compensate for this limitation.

SUMMARY

The development of alternatives and the data sought in the Search Phase are guided by and dependent upon the way we formulated the underlying decision. Choices provide the basis for a decision to be made. Alternatives are the potential ways that the decision maker can use the resources at his disposal. They can also be seen as various ways to fill the gap between the current and desired situation. A systems view describes a course of action as one possible way that the system could be operated. Alternatives are found in many different ways. The status quo should be considered, if only as a reference point to compare the viability of new options. The decision maker's guidance often establishes specific choices to be considered, but looking beyond these may identify the more effective alternatives. However, the primary source for alternatives will probably be the Decision Process itself. Many of its activities are especially designed to identify better ways to achieve the objective. Try to keep the number of choices manageable. Use creativity in seeking out new solutions but always check for feasibility before proceeding too far.

The research effort is the mainspring of the Search Phase. Through it we are able to define more clearly alternatives, seek out the many locations where supporting data may be found and organize and display the material collected. Data, which in the past was very hard to find, may now be very difficult to separate from the tons of output provided by the new computer age. Relevancy is the key. We are looking for information that differentiates between alternatives, data that makes it possible to make an objective choice between alternatives. Two record keeping activities are

important. First, the manner in which data are displayed will be of considerable help to the evaluation process. Second, keeping track of missing data will help to focus the research effort on the essential pieces of information.

Developing alternatives is definitely an innovative process rather than just a procedure. It will make good use of the skills of a creative person. Finally, it is important to remember that no choice will ever have perfect information upon which to evaluate the alternatives. When the time for making the decision begins to compress the Decision Process, move on to the next phase. There will be many other opportunities to continue the research effort.

CHAPTER V

THE QUANTITATIVE ANALYSIS OF ALTERNATIVES

At this point in the process, objectives have been identified and possible courses of action have been developed. We have collected supporting data that define these choices and the environment that surrounds them. It is now time to measure the performance and cost of the alternatives, to compare their relative merits and deficiencies. This portion of the Decision Process is called the Evaluation Phase.

One major problem must be faced as we begin to evaluate alternatives. With few exceptions, all choices in a decision have both quantitative factors that can be numerically compared and subjective factors that are not so easily quantified and must be assessed by using some form of verbal description. The difficulty arises when we try to mix quantitative and subjective factors in the same evaluation process. Many things can be done with numbers that cannot be done with those things that are not quantified. We have formulas, equations, simulations, and calculations that can solve very complicated numerical relationships. But try to include just one subjective factor like "softer," "less controversial," or "flexible" and the ability to compute a simple equation rapidly deteriorates. One practical solution is to separate the evaluation of quantitative factors from the process of comparing the subjective factors in a decision. This is the approach used in the Decision Process. In this chapter we will deal with the quantitative analysis of alternatives. Later we will discuss how the subjective factors can be evaluated and compared. Then we will suggest methods for bringing together the quantitative and subjective evaluations, interpretating the results, and arriving at a ranked preference for alternatives.

Quantitative Analysis, as we call this portion of the Evaluation Phase, is simply a numerical comparison of the alternatives. It is designed to answer two basic questions: what differences in cost and effectiveness of alternatives can be determined; and how well each course of action will achieve the objective. More often than not, quantitative analysis will serve as the initial, and perhaps the primary discriminator among the possible choices. Fully thought out decisions must, however, look beyond that which is collectable and measurable. To stop evaluation at the end of the quantitative effort is to ignore many factors in the decision, not because they are not important, but because they are not quantitatively measurable. The second part of the Evaluation Phase is called Subjective Analysis and will provide the means to deal with these remaining factors.

THE PURPOSE AND NATURE OF QUANTITATIVE ANALYSIS

The primary purpose of quantitative analysis is to evaluate alternatives in terms of effectiveness and cost. Recall that in the Formulation Phase, one of the tasks was to select a reasonable Measure of Effectiveness and a Measure of Cost. During the Search Phase we collected the data that was needed to define these two measures. The measuring scales will now be put to work to calculate the output produced and resources used by each option. Figure 1 illustrates how this relationship can be described on a graph.

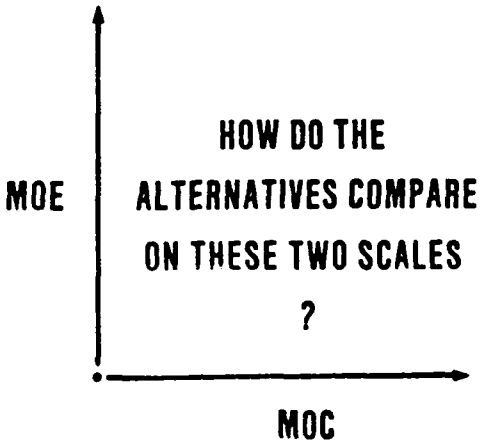

Figure 1: Measuring the Effectiveness and Cost of Alternatives

Another purpose of quantitative analysis is to determine the relative difference between alternatives. This will eventually lead to a rank ordering of the potential choices. Rank ordering is far more useful to the decision maker than simply identifying which alternative is the best choice. It is much better to be able to choose among productive alternatives than to have only one option to accept or reject. Finally, quantitative analysis should tell us how well the alternatives meet the objective. It may be that all of the options meet the objective and the decision will focus on selecting the one that does the best job. On the other hand, the evaluation may determine that none of the choices meet the objective. This may result in going "back to the drawing board," where we look for new alternatives or make an adjustment in the objective.

THE UNDERLYING CONCEPT

Measuring and comparing cost and effectiveness may seem relatively simple. The problem arises when both the benefits and the costs of the choices are different. Now one must first compare

the benefits of the options, then compare the costs, and then figure out a way to combine the results of these two evaluations.

The First Problem: Different Terms for Effectiveness and Cost

Consider the situation of a for-profit business. While corporate objectives involve more than just profit, it could be said that, for the most part, a company's effectiveness can be measured in dollars of income and its costs can be measured in dollars of expense. It then follows that the basis for decision can be stated as choosing whatever alternative maximizes income minus expenses. However, as in most not-for-profit organizations, the military cannot realistically express effectiveness and cost in a common term. In Defense matters, the effectiveness of various alternatives cannot normally be measured by dollars. Instead, effectiveness is tallied in Defense related terms such as pounds of bombs delivered on target, probability of kill or number of reenlistments. Comparing these measures with resource costs, which are often measured in dollars, is a situation that calls for another method of comparison.

The Second Problem: Differing Values for Effectiveness and Cost

The military decision maker's problem of dissimilar effectiveness and cost measures is further compounded by another frequently encountered condition. Consider Table 1 below which illustrates the four possible types of effectiveness/cost situations that can be encountered in a decision situation.

Situation	How Alternatives Compare		The Rule for Deciding
	in Effectiveness	in Cost	
1.	equal	equal	Choose any alternative or use subjective factors to decide
2.	unequal	equal	Pick the best performer
3.	equal	unequal	Pick the lowest cost
4.	unequal	unequal	?

Table 1: Different Effectiveness and Cost Relationships

The first situation identified is one in which the alternatives being considered provide the same effectiveness and also have the same cost. This is depicted in Figure 2. While this is a highly unlikely situation in complex decisions, it is fairly common in day-to-day decisions. For example, two lubricants from different manufacturers which both provide the same amount of protection at the same cost. If the alternatives are in all respects equal, then any of them could be rationally chosen. More realistically, however, the final choice would depend on how the alternatives fared when the factors not included in the quantitative analysis were considered (i.e., the subjective factors).

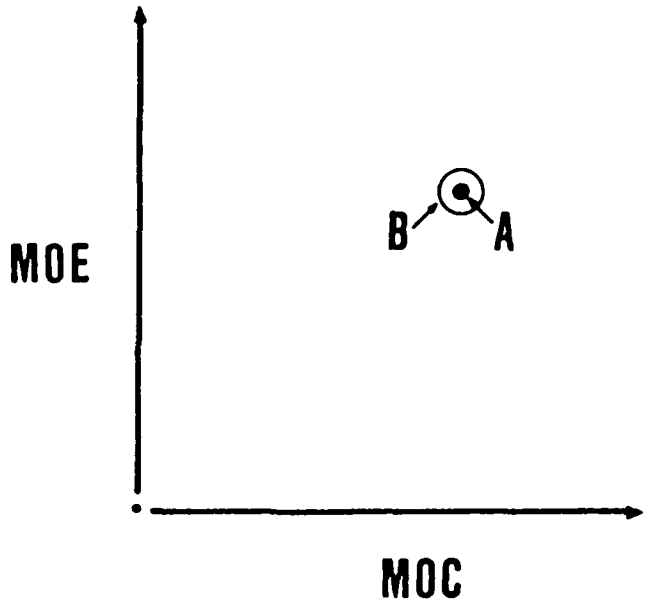

Figure 2: Equal Effectiveness, Equal Cost Alternatives

Situation Two illustrated in Figure 3 on the next page is one where alternatives have equal cost but different levels of effectiveness. Request for Proposals (RFPs) that have stipulated a cost ceiling often set up this decision situation. The rational choice in this case would be for the better performer (assuming that it provided enough effectiveness to satisfy the requirement).

Situation Three is depicted in Figure 4 on the next page. There are many examples of this relationship in the Defense environment. Alternatives that have been developed to meet weapon system requirements often fall into the equal effectiveness, unequal

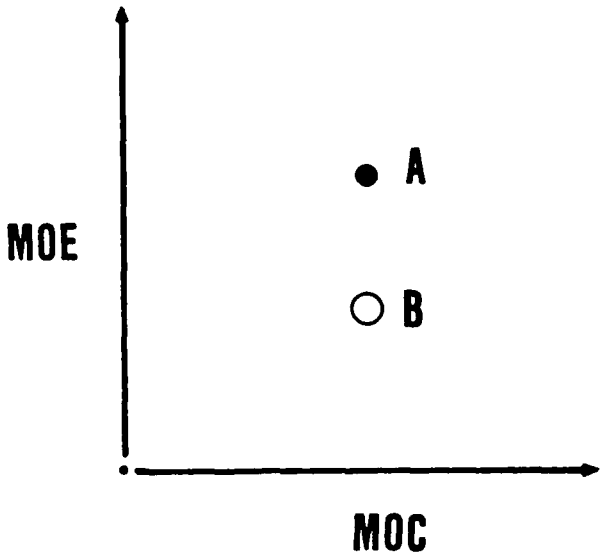

Figure 3: Unequal Effectiveness, Equal Cost Alternatives

cost preferred because it offers the same effectiveness for less cost (assuming B offers enough performance, and we can afford to pay for it).

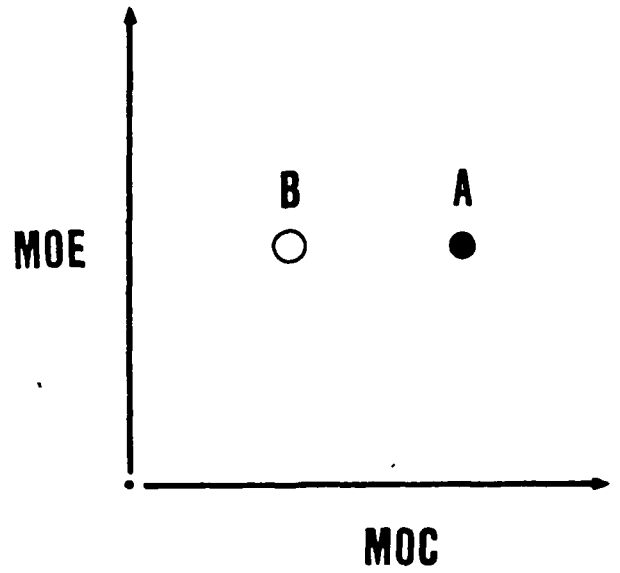

Figure 4: Equal Effectiveness, Unequal Cost Alternatives

The last situation in the table is the one which Defense decision makers most frequently must face, occurs when the

alternatives produce different effectiveness and have different costs. Figure 5 reflects such a situation. Here A is less expensive but also is less effective. Alternative B is a better performer but costs more. How should preference be ordered in such a situation?

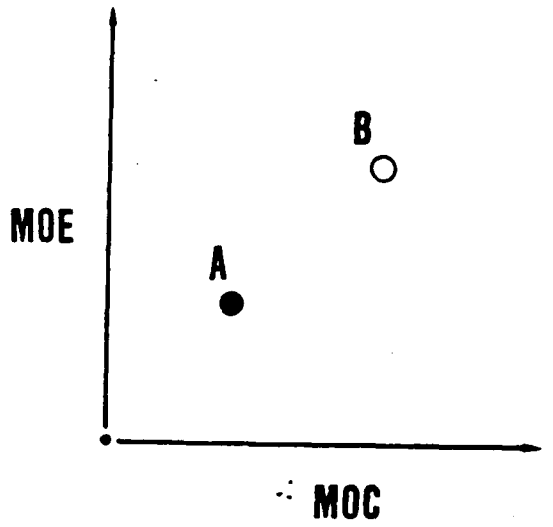

Figure 5: Unequal Effectiveness, Unequal Cost Alternatives

Needed: A Rule for Making Decisions

To objectively rank order the preference for alternatives shown in Figure 5, it is necessary to have a rule--a standard or a test upon which judgment is based. This is especially true in complex situations where one alternative does not dominate the others in all areas of comparison. How should we choose in the situation where one option is less costly but another option is better able to achieve the objective? It is essential to the Decision Process that we develop a decision rule that explicitly states how we are going to rank order the alternatives. Why do we choose alternative A over B? Does it cost less? Does it provide more benefit or effectiveness? Is it the only choice that meets the objective? We must have a rule for deciding.

In the next part of this chapter we will further develop the concept of a criterion. However, it is very important at this point to realize that there are two types of decision rules generally used in Defense Analysis.

Select the minimum cost alternative. Often called the "fixed effectiveness" approach, this rule establishes a point on the

effectiveness (MOE) scale which represents a desired or required level of output. All alternatives that meet or exceed that required level of effectiveness are then compared and ranked in order of lowest cost.

Select the maximum effectiveness alternative. With this decision rule we establish a point on the cost (MOC) scale which represents the desired level of cost or a budget limit. The output produced by each alternative that fits within the cost constraint is compared and ranked in order of the maximum effectiveness. This is often called the "fixed budget" approach, recognizing that we order preference of alternatives by the most effectiveness within a budget constraint.

It is important to note that quantitative analysis gives no "extra credit" for alternatives that offer more than the required level of effectiveness. This may seem to be an incorrect conclusion. We shall see later, however, that if such a difference in effectiveness is relevant to the decision, it can be reevaluated during the analysis of subjective factors.

The concept of a decision rule lies at the heart of the activities of the quantitative analysis portion of the Evaluation Phase. It serves as the means for quantitatively rank ordering alternatives in those decisions where effectiveness and cost are measured in different terms and are not equal for the alternatives. We shall see as the steps of quantitative analysis are developed, that this decision rule is called the quantitative criterion and serves as the keystone of this part of evaluation.

THE STEPS OF QUANTITATIVE ANALYSIS

Selecting the quantitative criterion is the first of four activities that make up the quantitative analysis portion of the Evaluation Phase. The second step is to develop a model, or several models if necessary, which we can use to estimate how well each option would satisfy the system objective. The basic quantitative analysis is then conducted, producing an initial rank ordered preference for alternatives. Finally, we will perform sensitivity analysis to see if a change in any of the assumptions we made would alter our preference for alternatives. The end product of quantitative analysis will be a rank ordered set of alternatives reflecting the preferred courses of action based on the quantitative information available.

Establishing the Criterion for Quantitative Preference

It may sound redundant to say that the first step in quantitative analysis is to "decide how we will decide." Yet, in

every rational decision made in life, some form of rule for deciding has been intuitively or explicitly established. It may be "choose the lowest cost," "pick the fastest way," or "use the first one that works." Each decision must have a way to rank order the alternatives being considered.

THE CRITERION IS A STATEMENT DEFINING THE RELATIONSHIP BETWEEN EFFECTIVENESS AND COST THAT SERVES AS A GUIDE TO THE QUANTITATIVE RANKING OF ALTERNATIVES.

Given that we are in the habit of intuitively defining a decision rule in day-to-day activities, it is puzzling why setting up an explicit criterion seems to be a challenge. Stating the criterion will insure that we decide how we are going to compare alternatives before we start the evaluation. A lot of misdirected effort can be avoided. Improved communications will also result from a well-stated decision rule. Whether it is one person preparing an analysis for others or several individuals working together on a decision, an explicit criterion will provide a common understanding of how the options are to be compared.

The Decision Process normally uses one of two types of quantitative criteria: select the minimum cost alternative, or select the maximum effectiveness alternative. In conceptual terms they are usually expressed in the following way:

Maximize the effectiveness produced for a fixed level of cost.

Minimize the cost to achieve a required level of effectiveness.

Notice that in each of the criterion, a point is fixed on one of the measuring scales, either on the Measure of Cost or on the Measure of Effectiveness. This fixed point is what permits the maximizing or minimizing of the other scale. Remember that it is the criterion that identifies this constraint. The MOE and MOC never are single points but are the scales upon which this point is established.

The key to a really useful criterion is a clearly defined relationship between effectiveness and cost, one that has practical use in the decision being considered. Accordingly, the quantitative criterion should use the Measure of Effectiveness and the Measure of Cost that were identified in the Formulation Phase. Rather than use general terms such as: "achieve the required effectiveness," "minimize the cost," or "maximize effectiveness," the decision rule should include the specific terms which defined the MOE and MOC.

There are two precautions that one should observe when stating a criterion. Avoid the temptation to maximize and minimize at the

same time, i.e., "maximize effectiveness and minimize cost." It is rare that any alternative can provide the most effectiveness of any of the choices and, at the same time, cost the least. Imagine the quality of a Cadillac for the cost of a Ford Escort. It is far more reasonable to look for a required level of performance and then minimize the cost, or to place a limit on the cost and maximize the performance that can be achieved.

We should also be very cautious about using ratios as criteria. Ratios have the potential for being very misleading because they tend to ignore two very important factors: 1) we may require a specific level of effectiveness, or 2) resources may be restricted to a fixed level. For example, one option may have a very high effectiveness to cost ratio, but the total output is far short of the required level. Another high ratio choice may produce outstanding effectiveness but exceeds the available budget. Ratios can be useful when trying to compute how much of one type of alternative to produce, buy or operate. 1

Developing Models.

Models are no more than simplified representations of the real world. There are at least four types of models: iconic, analog, symbolic and conceptual. Aircraft models, wind tunnels, and even sand castles are examples of iconic or scale models. Graphs and navigation charts are analog models that don't look like the real thing, but portray the same set of relationships. Mathematical formulas and accounting formats are models where symbols are substituted for physical properties. They are usually in equation form; for example, Distance = Rate X Time (D = RT). Less precise conceptual models are also frequently used. The definition we use for a model bears that out.

> MODELS ARE SIMPLIFICATIONS OF REAL WORLD SYSTEMS WHICH ARE USED TO EVALUATE THE EFFECTIVENESS AND COST OF ALTERNATIVES BEING CONSIDERED IN A DECISION.

More often than not we can expect to use mathematical models in the defense decisions. One can imagine that for a complex decision the structure of a model for evaluating alternatives might be quite detailed, although they certainly do not need to be overly complex to be useful.

Some Guidelines for Developing Models. When constructing models for quantitative analysis, try to remember that they should use previously developed elements of the Decision Process and still

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1. See the note at the end of this chapter for an expanded discussion on using ratios for deciding on levels of activity.

leave room for open-minded thinking. The initial structure of the model should flow from the description of the system, particularly how it uses resources and produces desired output. The process for estimating cost or effectiveness of the alternatives should directly relate to the MOE and MOC. The model should flow logically from start to finish.

When using models, one should try to use as much of the significant quantitative data as possible. However, caution should be exercised as well. Even "relevant" data comes in various levels of importance. Second and third order information, if extensively used in the model, can cloud the evaluations generated by the models. However, do not discard important information that doesn't happen to "fit" in the qualitative analysis. That data can be used later in the Evaluation Phase when we conduct the subjective analysis.

Conducting the Basic Quantitative Analysis

Actually doing the mathematical computations is perhaps the easiest part of qualitative analysis. Unlike the thought provoking development of the criterion and the models, this step is primarily a mechanical activity. To carry out the basic quantitative analysis we first substitute into the model the data collected during the Search Phase. Care must be taken at this point to insure that the data used is consistent with the stated criterion. If our decision rule is based on maximizing equal cost alternatives, then we must be sure that all options tested in the model are evaluated at the same cost. Similarly, if the criterion used is minimizing cost for required effectiveness, then all alternatives must be evaluated at the same level of performance. The actual calculations are then made to determine the amount of effectiveness and cost generated by each alternative. Following this we apply the criterion to set up a rank order preference of the courses of action.

Sensitivity Analysis

We have emphasized several times that complex defense issues will involve considerable uncertainty, much of it quantitative in nature. Some doubt will result from not knowing the value of a particular variable or realizing that it is too expensive to obtain the information. Data with clearly defined ranges of value can also cause uncertainty if we don't know what specific number in that range will be used in the analysis.

One of the hallmarks of the Decision Process is the manner in which imperfect quantitative information is handled. The technique used is to arbitrarily reduce uncertainty early in the process so that we can organize and evaluate factual relationships. In the

Formulation Phase we make assumptions to temporarily eliminate the uncertainty in data. During the Search Phase, our research takes in a great quantity of uncertainty in the form of estimates and forecasts. We arbitrarily reduce this mass of information to specific data points so that we can use the information in the evaluation process. For missing data we may have made "educated" guesses. At some point in the process, however, we must face up to the uncertainty that we have created, set aside or overlooked. What if the assumptions are not correct? What if the summarizing of data did not give us good information? Sensitivity Analysis answers these questions.

SENSITIVITY ANALYSIS IS THE REPEATING OF ANALYSIS TO DETERMINE IF A REASONABLE CHANGE IN QUANTITATIVE ASSUMPTIONS OR DATA ESTIMATES WILL CHANGE THE RANK ORDER PREFERENCE FOR ALTERNATIVES.

How much sensitivity analyses to do should be decided very carefully. Only those assumptions and estimates for which there is a good deal of uncertainty should be tested. Too much sensitivity analysis can change the focus of the entire Decision Process and the Defense executive can get lost in a morass of "what ifs."

Carrying out the sensitivity analysis is very easy. The new value is substituted in the model for the original assumed or estimated value and the computations are repeated. The alternatives are then displayed again in accordance with the criterion. If there is no change in the rank order preference of alternatives, then the decision is <u>not</u> sensitive to that variation in the uncertain value. On the other hand, if the preference for alternatives does change, then the decision <u>is</u> sensitive to that variable and we should try to reduce the uncertainty in that piece of information. When a particularly sensitive variable is found, it is good practice to test values both above and below the original data point to determine exactly where the preference for alternatives changes.

The use of sensitivity analysis is very important to the confidence one has in the Decision Process and the overall viability of the decision made. Uncertainty cannot be eliminated. However, if one is able to determine how much that uncertainty can affect the choice of alternatives, then its impact is largely negated. It has been said that "it is better to be approximately right, than to be exactly wrong."

SUMMARY

In the Evaluation Phase we compare alternatives by estimating and evaluating their benefits and costs. The first difficulty faced is the fact that all decisions have both quantitative and subjective

factors to consider. The Decision Process is structured to separately evaluate these two determinants of the decision and then combine the results in the Interpretation Phase. This chapter has focused on the first of these--quantitative analysis.

The purpose of quantitative analysis is to evaluate alternatives by comparing the effectiveness and cost of each choice. We are interested in determining the relative difference between alternatives and how well they achieve the objective. Unequal values among the choices and the absence of a common measure for cost and effectiveness complicate the process. Yet, having unequal cost values for alternatives and also unequal performance values is the typical challenge in the area of major Defense decisions. To cope with this situation we need an explicitly stated decision rule which will clarify how we are going to choose between the courses of action. One of two possible criteria will normally be used: to maximize the effectiveness produced for a given cost expended; or, to minimize the cost to achieve a desired level of effectiveness. We must never try to do both at the same time.

Four steps are used to carry out the process of quantitative analysis. Developing the quantitative criterion is critical because we can't evaluate options without it. In addition, a criterion causes us to analyze the very logic underlying the decision. Setting up the models for evaluation involves the translation of the system to a more simplified description, usually a mathematical equation. The basic quantitative analysis takes place next, computing the values of effectiveness and cost for all of the alternatives, and then using the criterion to establish the initial rank ordered preference. Finally, we use sensitivity analysis to determine how the uncertainty that was identified earlier in the Decision Process will affect our rank-ordered preference for alternatives. If a change in the uncertain value does not affect the order of preference, then the decision is not sensitive to that variation. However, if the ranking of choices is changed, then we must attempt to reduce that uncertainty or couch our decision accordingly. When the quantitative effort has been accomplished, the Subjective Analysis portion of the Evaluation Phase awaits our attention.

SUPPLEMENTAL NOTE

The effectiveness of an alternative will probably change as the quantity of resources used is adjusted. Furthermore , this change may not be a direct proportion between effectiveness and cost, i.e., linear. Suppose we are considering two alternatives. Analysts have produced estimates for their effectiveness contingent on the amount of resources consumed. The data is displayed in Figure 6.

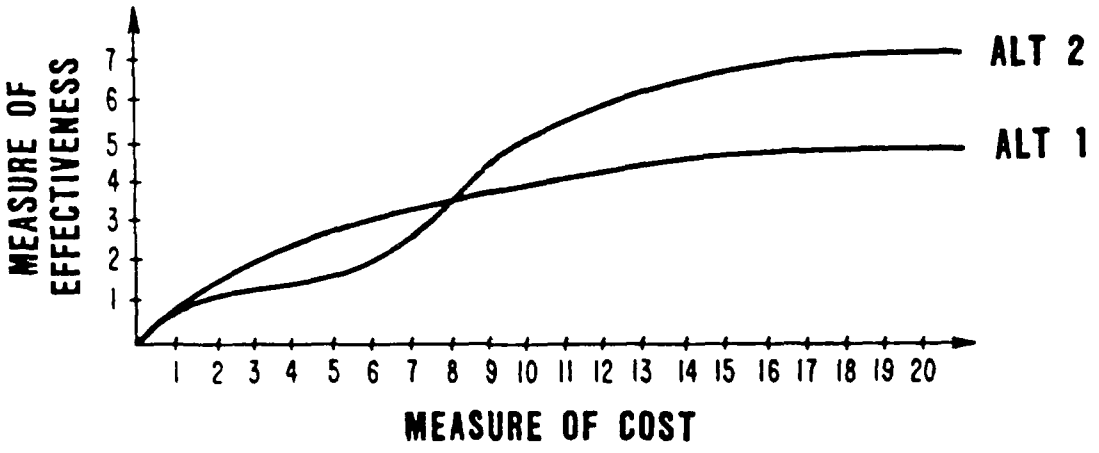

Figure 6: Effectiveness of alternatives over a range of costs

In this situation, the projected effectiveness from each of the alternatives varies as we spend more resources. Both choices demonstrate diminishing returns. As more resources are added, we continue to get more effectiveness but at a declining rate of increase.

There is a temptation to apply "marginal analysis" in this situation. Marginal analysis is a quantitative technique which evaluates the extra cost associated with attaining the last unit of effectiveness (marginal cost) or, similarly, the extra effectiveness gained by the additional unit of cost expended (marginal utility). Marginal analysis would lead us to choose an alternative in the range that offers increasing effectiveness for each additional unit

of cost. While marginal analysis can give us insight into system efficiency, it does not provide to us a clear indication of preference. This is because the relation of cost to effectiveness, or how much "bang you get for the buck," usually varies over the range of possibilities. Like ratios, marginal analysis is of limited value in deriving preference unless we identify the required performance or limit to available resources.

CHAPTER VI

SUBJECTIVE ANALYSIS

In any decision where there are extensive calculations of cost and other quantitative factors, one can be assured that there is probably a comparable number of non-quantitative elements that will affect the choice of alternatives. Such aspects as quality of life, morale, compatibility, ease of handling, user friendly and countless other qualitative descriptions can exert a major influence on the outcome of a decision--if given the opportunity. When the weighing of pros and cons of alternatives is done mentally, our thought process seems to be able to combine both the quantitative and qualitative elements into a single evaluation of the choices. But in decision processes that are put in writing because of their complexity, it is very possible that the more finite and tangible quantitative elements will overshadow and drive out those factors that are not so easily manipulated. To avoid this potential analytical weakness, we must have a specific part of the process that deals with those aspects of a decision that are not readily quantified. This is Subjective Analysis, the second part of the Evaluation Phase.

THE ROLE OF SUBJECTIVE ANALYSIS

In Subjective Analysis we evaluate the effect that factors not included in the quantitative analysis will have on the choice of alternatives. This form of analysis cannot rely on mathematical models or formulas to carry out the process. Instead, professional judgment is used as the main tool for analyzing the qualitative factors that affect the choice of alternatives. We will define the process as follows:

> SUBJECTIVE ANALYSIS IS THE USE OF JUDGMENT TO IDENTIFY, DISCUSS AND EVALUATE HOW THE FACTORS NOT INCLUDED IN THE QUANTITATIVE ANALYSIS WILL AFFECT THE CHOICE OF ALTERNATIVES.

No matter how good a quantitative analysis might be, there are always other factors that must be considered to arrive at a fully developed decision. Some of these factors have quantitative values but just do not fit in the model. Others are external to the system

being evaluated or are difficult to quantify. The great majority of these "other factors" are qualitative in nature, measured not by numerical computation but by judgment.

It is usually easy to recognize that these factors are important. The difficulty comes in deciding how to deal with them. One of the most frequent ways to cope with qualitative factors in scientific decision making is to exclude them by discounting their importance or considering it too hard to include them in the analysis.

A more realistic approach to dealing with qualitative factors is to tackle them directly and explicitly, in spite of the increased complexity they bring into a decision. By directly we mean that the overall process used for decision making should have the evaluation of non-quantitative factors as a formal part of the methodology. The steps for carrying out the activity must be clearly defined and functionally usable rather than just abstract ideas. When tackling qualitative factors explicitly we focus on the rational nature of the evaluation process. The main challenge of Subjective Analysis is to avoid being drawn into emotional or biased assessments of the factors and how they affect the alternatives. By relying on professional judgment and forcing the process to be open and procedural, objective evaluation is more likely to take place.

The Relationship Between Quantitative and Subjective Analyses

As suggested earlier, subjective analysis is separated from the evaluation of quantitative factors because there is no accurate way to measure their individual qualities on a common scale. With separate analyses we insure that both quantitative and qualitative factors are evaluated, and that assessment is accomplished with techniques that are appropriate for the type of factor being considered.

Having both quantitative and subjective analyses does raise two potential difficulties. The first is a question of sequence. Which should come first? This may seem like a moot point, but not really. Sequence can affect both process and outcome. The logic introduced previously argues that quantitative analysis should be done first because of its finite and measurable qualities.

The second difficulty that may be encountered by dividing the evaluation into two separate activities is the question of emphasis. There are many reasons why quantitative factors often appear to dominate the evaluation of alternatives. Having a finite quality and apparent accuracy, we seem to be intrigued by mathematical formulae. Quantitative data can be manipulated to provide measurable differences between alternatives. Because of well-developed mathematical techniques there is considerable motivation

to apply these tools to the complex problem. Most would describe the factors surrounding a complex issue in the Defense Department as being a combination of quantitative and subjective factors with the balance more frequently favoring the latter. Therefore, recognizing the apparent dichotomy between reality and the penchant for computations, one of the important goals of subjective analysis and the Interpretation Phase that follows is to insure that qualitative factors are given equitable consideration in the evaluation of alternatives.

Difficulties that come with two separate analyses in the Evaluation Phase can be overcome with a conscious effort to approach the overall evaluation objectively. The fact that subjective analysis is a formal part of the effort will help to solve the problems of dealing with qualitative factors that exists in many other rational decision making processes.

Subjective Analysis: The Application of Judgment

The term Subjective Analysis means that judgment is used to determine the relative value and relevance of the various alternatives under consideration. This is in contrast to quantitative analysis where mathematical logic controls the evaluation of alternatives. Judgment is exercised in two ways. First, it is used to decide what factors should be considered in the subjective analysis. This is where professional understanding is essential in determining what is relevant. As H. Simon points out in his concept of bounded rationality, "Only those factors that are most closely connected with the decision in cause and time can be taken into consideration. The problem of discovering what factors are, and what are not, important in any given situation is quite as essential to the correct choice as a knowledge of the empirical laws governing those factors that are finally selected as relevant." 1

The second way that judgment is exercised in Subjective Analysis is to actually evaluate the subjective factors that have been selected for consideration. Unlike quantitative analysis where a model is used to compare the numerical relationships, Subjective Analysis must use judgment as the tool for evaluating factors and their impact on the alternatives. Determining the impact of "quality of life" factors on the choice of homeporting for a new Carrier Battle Group could draw on survey results but would ultimately rely on the wisdom of experienced military officers. There is no magic formula for arriving at the "right" assessment of factors in subjective analysis The role of judgment in this part of the evaluation process is the critical determinant for success.

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5 Herbert A. Simon, Administrative Behavior, 3rd ed.(New York: The Free Press, 1972), p. 82.

Subjective Factors: A Catch-all Term

As a term of convenience, any information which is relevant to the decision but not considered in the quantitative analysis is called a subjective factor. This catch-all term may seem arbitrary but assists in the Decision Process by bringing together all of the factors not yet considered which have a bearing on the decision. There are two broad categories into which subjective factors can be grouped:

Other Quantitative Factors. In complex decisions the model used to evaluate quantitative factors invariably must be a simplified representation of the real world. Usually there are numerical elements that must be omitted, either because of the simplified model or because they were not measurable by the same scale. As a very simple example, suppose that we are evaluating alternative aircraft to be used in strategic airlift. A very detailed model, using all known quantitative factors, could be developed that simulated every aspect of the airlift operation. Experience has shown, however, that one performance measure will dominate all others in this system, the ton-mile productivity (how much cargo can be carried how far in what period of time). Therefore, we can usually simplify the effectiveness model to the calculation of this MOE. This excludes from the model several other quantitative factors, either because they are not a part of the computation of ton-mile productivity or because the factor is not comparable because of a difference in measuring scales (MOE). Excluding them from the model does not mean that they should not be considered. It just means that they must be evaluated in the subjective analysis if they bear on the decision.

Subjective Factors. Up to this point we have used many different terms to describe this category of factors: qualitative, non-quantitative, other, higher level, and even non-quantifiable factors. They all suggest that the factors do not have a specific or finite value and that evaluation of their impact on the choice of alternatives is not possible in quantitative terms. The debate about whether or not the factors could be quantified is an argument better left to the theorists. The point is that, for the decision under consideration, the factors are not quantified. Perhaps the data was not available. It could have been too costly to collect the data. Maybe the finite numerical values were not critical to the choice of alternatives. It is more likely that the factor was not quantified because the value was not calculable by any reasonable means. Finally, subjective factors include information for which no satisfactory scale of measurement exists. Stress, morale, deterrence and quality of life are factors which fit into this category.

A Final Note on Subjective Analysis and Subjective Factors

Unlike factors in quantitative analysis which can be expressed in finite terms, analysis of the impact of most subjective factors on alternatives must be stated in relative terms such as: more quickly, less expensive, more productive and other indicators of relative difference between the choices. The subjective analysis may be no more than a "does" or "doesn't" assessment of how a factor affects an alternative. Even if numbers are involved in the subjective factor, it still requires judgment to assess the relative impact on the choice of alternatives.

THE STEPS IN SUBJECTIVE ANALYSIS

There are several ways that an analysis of subjective factors could be accomplished. At the low end of a scale of complexity are the approaches that are very unstructured and tend to identify the subjective factors and evaluate them at the same time. Listing the advantages and disadvantages of alternatives is a typical example. At the other end of the scale are techniques that are very formalized and constitute a complete analytical process in and of themselves. The following three-step approach for subjective analysis used in the Decision Process is one workable way to evaluate subjective factors while insuring that the process remains objective and will fit nearly all decision situations.

Step One: Identify the Factors

The first task in Subjective Analysis is to determine which factors should be considered. Where do we look? Which do we choose? It is helpful that this analysis follows the quantitative effort because the great majority of relevant factors have already been uncovered and we can look primarily for information that has been identified but not yet been evaluated. Good use can be made of the iterative process by returning again to the beginning of the Decision Process and looking at the elements in each phase to see if subjective factors are involved.

A primary source is the list of key factors initiated during the Formulation Phase, particularly those factors not used in the quantitative analysis. A second source of subjective factors is the information gathered in the Search Phase. Although this phase is primarily oriented toward finding numerical data, many subjective factors will surface during the research effort. In addition, any factors which fell out of the quantitative analysis can be readdressed in the subjective analysis. All subjective factors should be identified in a very explicit manner, recognizing that

they do not have the finite characteristics that quantitative factors have. Therefore, they must be specifically listed to ensure that they remain under consideration.

The question of which factors to include in the analysis is a more difficult to answer. The first discriminator is relevance. Judgment is exercised to identify factors which directly affect the way the decision is to be made. There are also other subjective items of information to consider which may affect the evaluation of alternatives. Whether or not a factor is included in the analysis also depends on its importance. Limitations of time and effort keep us from considering every possible factor. Again, judgment is the tool used to make this determination. The bottom line in identifying subjective factors is that we must assemble a list of factors that are relevant to the decision and have not yet been evaluated in the quantitative analysis.

Step Two: Discuss the Factors

This is the area where operational experience plays a very important role in the analytical process. Each subjective factor should be explored to determine the clearest way to express the significance of that factor on the decision, to indicate the potential range of importance the factor may take, and the relationship to overall objectives. This defining the essence of the subjective factors can be a simple process of reasoning or a complete analysis of its own, depending on the importance of the factor on the decision. The desired result is a more specific understanding of the subjective factor and how to measure its impact on alternatives.

Step Three: Evaluate Each Factor

To determine how each subjective factor affects the alternatives is the end product of subjective analysis. This is not too difficult for the other quantitative factors, where there is a numerical basis to choose between alternatives. However, for subjective factors the evaluation is far more challenging. Here we must evaluate the impact of factors on alternatives using verbal descriptions, usually indicating relative differences between the choices. Thus, the evaluation may indicate "excellent," "very good," and "poor" as the assessment we might expect with three different alternatives. It is good practice to use terms in which differences are reasonable easy to see. Using "a bit less useful" and "second choice" in the same evaluation does not communicate too well.

There are two helpful guidelines that should be followed when evaluating subjective factors. First of all, be honest in the evaluation by assessing the impact of the subjective factor on all

alternatives, not just the choice most favored by the factor. The second guideline for subjective evaluation is to avoid "double counting" the factor. We do this by considering the same subjective factor to be the advantage of one alternative and the detriment of a second. A much better approach is to start at a neutral position and measure just the positive benefits for all alternatives created by a subjective factor or the negative impact of a detrimental factor.

Depicting the Results of Evaluation

The manner in which subjective evaluation is depicted in writing can vary considerably. The most basic form would be by narrative comments that identify, discuss, and evaluate each factor; the bottom line being a statement of how the alternatives fare with respect to that factor. However, when there are many factors to be evaluated, this approach may not be adequate to summarize the overall impact on the decision. In such cases it can be helpful to add a summary to this narrative format. Used frequently is a matrix listing the alternatives along one axis and the various subjective factors along the other. In its simplest form the responses in the matrix briefly reiterate the evaluation expressed previously. It may only be a "yes/no" assessment or a checkmark indicating support or non-support of an alternative. A more finite display is a "scoreboard" approach in which a scale is devised (from zero to a number high enough to indicate relative difference) and the impact of the subjective factor on each alternative is established. Evaluation of subjective factors can be considered complete when the impact of each factor on all of the alternatives has been determined.

A summary of how all of the subjective factors affect the alternatives is normally deferred to the Interpretation Phase unless there are a great number of subjective factors, and dealing with them along with the quantitative analysis would be too cumbersome. In that case a summary display could be developed using the concepts explained later in the Interpretation Phase.

SUMMARY

In the final part of the Evaluation Phase we evaluate the subjective factors affecting the choice of alternatives. Judgment is critical to the success of this activity and a three-step approach is suggested for subjective analysis. We identify the factors to be analyzed by their relevance and importance to the decision. We next discuss each subjective factor to insure that it is fully understood and it has a reasonable means for measuring the difference between alternatives. Finally, we evaluate each factor

to determine its effect on each of the alternatives. Depicting the results can be done in narrative form or by the use of a matrix if the size of the task requires it.

CHAPTER VII

THE INTERPRETATION PHASE

The Interpretation Phase brings together all of the previous phases of the Decision Process and provides the integrating format for completing the analysis up to the point of decision. Whether or not it leads to a good decision will depend on how well the phases are put together and what adjustments are made to accommodate the external environment. However, a decision of some sort can always occur, regardless of the quality of interpretation. The problem is that it may not be a rational one, nor one which makes the best use of resources.

Interpretation is not accomplished in one large step but is divided into several related activities. A method is then developed to combine the results of the quantitative and subjective analyses so that a rank-ordered preference for alternatives can be established. This activity needs both judgment and intuition to determine the proper relationship among the previously evaluated factors. As a final task, we draw conclusions from the results of interpretation and, depending on our role, either make the decision or offer recommendations to the decision maker.

Although interpretation can be quite difficult, bringing the Decision Process to a successful and productive conclusion will make the effort worthwhile. The most formidable part comes when trying to combine the results of the quantitative and subjective analyses. Here we are trying to overcome the same analytical conflict that caused the two types of analysis to be separated in the first place. Further challenges to a successful interpretation effort may occur when we introduce relevant outside factors that affect the way the decision is made.

How important the Implementation Phase is to the entire Decision Process goes without saying. Without this phase the entire Decision Process is inconclusive and potentially non-productive. Interpretation serves as an integrator of all of the activities of the process to this point and the foundation upon which the decision will be made. Essentially, this phase is the executive summary of the entire analytical effort.

THE PROCESS OF INTERPRETATION

There are many ways that one could interpret the results of the Evaluation Phase. Which method to use depends on where the

critical factors of the decision are located. Are they in the quantitative or subjective portion of the evaluation? To determine where those critical factors lie and especially for decisions where a lot of quantification is involved, the Decision Process offers a very productive series of steps for interpretation. These activities provide an integrated display of all the factors and yet protect both the balance between quantitative and subjective factors and the objectivity of the decision. The process of interpretation includes: interpreting the results of quantitative analysis, combining the quantitative and subjective analyses into a summary display, and consideration of external factors which may influence how the decision is made.

Interpreting the Quantitative Analysis

Far too often we think that the quantitative analysis is over when the numbers have been calculated. We have the answers! It doesn't matter what the numbers are, just as long as they have been computed correctly! This is a very good time in the Decision Process to step back and take a careful look at just what the numbers tell us. Are the numerical differences among the choices sufficient to affect the decision? Do cost and effectiveness meet the objective within the resource limitations? These questions should be answered before we attempt to combine the quantitative and subjective analyses.

We do a disservice to the overall Decision Process to use the reasoning that, if alternatives A, B and C can all produce the same effectiveness and B is less costly than the others, then alternative B is automatically the cost-effective solution and we can move ahead to consider the subjective factors. It is far more compatible with the intent of the Decision Process to interpret the relative values of alternatives, looking at the magnitude of numerical differences between choices as well as their absolute cost and effectiveness in relationship to the objective. For instance, let us use the hypothetical set of quantitative results in Figure 1 to illustrate the point.

Alternatives	Effectiveness Tgts destroyed	Cost (millions of $)
Alternative A	(equal in all alternatives)	$62
Alternative B		$22
Alternative C		$64

Figure 1: System costs to destroy 1,000 targets

Assume that destroying 1,000 targets is our objective. It is reasonable to argue that alternative B, which is $40 million less than the other alternatives, is the cost-effective solution. To rationally choose alternative A or C over B, there must be very important subjective factors that heavily favor either A or C. Note also that alternative A is a better choice than C, but the difference is so small that uncertainties in their computed values could easily reverse this preference. It would be more reasonable to interpret alternatives A and C as equal choices.

However, suppose that the costs of the options were as high as shown in Figure 2. Is the difference of $40 million now significant enough to confidently pick alternative B as the cost-effective solution? While that cost advantage is not to be ignored, how much uncertainty is involved in the computation of those costs? Would a small change in assumptions change the preference for alternatives?

Alternatives	Effectiveness (Tgts destroyed)	Cost (millions of $)
Alternative A	(equal in all alternatives)	$2600
Alternative B		$2560
Alternative C		$2610

Figure 2: System costs to destroy 1,000 targets

Thus the argument being made is that we should interpret the the quantitative analysis in terms of the relative differences between alternatives as well as the size of the difference relative to overall value. One should not conclude from this example that, if the quantitative analysis has shown that all alternatives have approximately the same cost, the analytical effort has been wasted. The absolute values of the choices are still important to the decision. In addition, we now know that, based on the quantitative analysis, we are indifferent as to the choice of alternatives, and the decision should have more weight placed on the subjective factors.

Let us look at one final example. Suppose that the results of the quantitative analysis are as illustrated in Figure 3. In this situation we recognize that alternative A is relatively expensive and, unless there are very compelling subjective factors, it should be eliminated. We also can see that, based on the quantitative data, we are reasonably indifferent to either alternative B or C being selected. In this case subjective factors will probably play a very important role in the decision to be made.

Alternatives	Effectiveness Tgts destroyed	Cost (millions of $)
Alternative A	(equal in all alternatives)	$3600
Alternative B		$2560
Alternative C		$3610

Figure 3: System costs to destroy 1,000 targets

This process of interpreting the quantitative analysis is often overlooked. It can, of course, also be applied to the effectiveness of alternatives as well as to the costs. As is true for most activities of the Decision Process, assessing the realistic impact of numbers on the decision should be done explicitly to convey to others the rationale used to rank order the courses of action. This will insure a more comprehensive approach to the decision.

Combining the Quantitative and Subjective Analyses.

At the heart of the Interpretation Phase is the effort to integrate the quantitative and subjective analyses and interpret what the combined results tell us about the choice of alternatives. It is essential that we bring the two analyses together in order to make sure that all relevant factors are considered. We also must avoid the pitfall of inadvertently letting one or the other analysis dominate the decision. In complex decisions where it is important to communicate the underlying rationale, the interpretive activity must be more explicit. Three ways for combining quantitative and subjective analyses are offered as a basis for interpreting the results of evaluation. The third approach, the summary display, is the most capable of objectively dealing with the complex decision.

Adding Subjective Analysis to the Quantitative Analysis. Because the quantitative model and the resulting numerical output provide finite values to alternatives, one of the easiest ways to combine the two analyses is to review the results of the subjective analysis and see if any of the factors would alter the rank ordered preference of alternatives as determined by the quantitative analysis. Although fairly simple to do, this tends to put the quantitative analysis in a dominant position, relegating the subjective factors to a modifying role.

Comparing the Alternatives Preferred by Each Analysis. A second way to combine quantitative analysis with the subjective analysis is to compare the final results from each of the evaluations. If both indicate that alternative A is the preferred

choice among three possible courses of action, the interpretation as well as the decision itself becomes much easier. If the quantitative effort indicates that choice C is a very poor choice and choice A is least preferred by the results of the subjective analysis, then the remaining choice B may become the preferred course of action. We must be careful about choosing a compromise alternative, however, since Defense Analysis is an optimizing process. Often it is better to let one or the other "best" solution dominate, rather than choose a solution that is not optimum in any sphere. Many would suggest that this is exactly the problem with the NATO all-purpose fighter aircraft, the Toronado. Several of its mission capabilities were scaled down to make them compatible in one airframe. When quantitative and subjective analyses indicate different preferences for alternatives or do not eliminate all but one choice, the value of this approach diminishes.

Combining Both Analyses into One Display. A third way to combine the quantitative and subjective analyses is to integrate the important factors that have been identified in the Evaluation Phase into one single display. This process may be as simple as using a "tally sheet" where we add up the strong and weak aspects of each alternative or a more comprehensive approach called the "summary display."

The Tally Sheet. A very simple way to interpret all of the important factors of a decision is by using a tally sheet. We are all familiar with such techniques as listing the advantages and disadvantages of an alternative, considering the pros and cons, or adding up the pluses and minuses. In each case, the alternatives are compared with each other and an interpretation made as to their relative importance.

The Summary Display. When we encounter complex decisions which have both quantitative assessments and subjective factors that play a major role in choosing, the Summary Display provides an effective way to interpret the results. Its purpose is to combine the two analyses so that all of the factors can be collectively viewed and iterpreted. The four part procedure for accomplishing the display is quite simple.

Step One: Form a matrix. In the initial step we form a matrix with the alternatives arrayed across the top and the factors to be considered listed down the left side. The factors to be used come from the two analyses of the Evaluation Phase. Quantitative factors are usually listed first, followed by those subjective factors considered important.

Usually we place only the results of the quantitative analysis in the summary display. Thus, if the effectiveness was set at a required level, then only the costs computed for the alternatives would be shown. If we fixed the cost of the choices at a specific level, then only the resulting effectiveness should be displayed. Other important numerical factors may be listed, but only if they

were not a specific part of the quantitative analysis calculation. Figure 4 depicts a general format for the summary display.

Quantitative and Subjective Factors	Alternatives		
	A	B	C
(Results of Quantitative Analysis; either effectiveness or cost)			
(Other Quantitative Factors; not in model)			
(Results of Subjective Analysis; list factors considered important)			

Figure 4: General format for the Summary Display

Step Two: Fill in the Matrix. The next step in preparing a summary display is to enter the results of the two analyses in the matrix, showing how each factor affects the choices being considered. For the quantitative factors, enter the actual value of the factor. For the subjective factors, this may be no more that a series of plus and minus symbols or a brief word description. If feasible, a ranking of how each subjective factor affects the alternative could be used, with a 1 indicating the preferred alternative, a 2 indicating the second choice, and so on.

A more specific way to show the assessment of subjective factors is by using a numerical index from 1 to 10, with 1 signifying a minimum impact and 10 signifying the greatest impact on the alternative. If the display is to measure both quantitative and subjective factors with one common index, then the values obtained in the quantitative analysis will have to be translated to index values for each of the alternatives. However, changing finite outputs to a common index may be counterproductive, given that the former are based on actual values. It is usually more reasonable to leave quantitative factors in their original form and only list the subjective factors with a numerical index.

For example, if we were interpreting the analysis of a Counterforce Ballistic Missile (CFBM) decision, an initial Summary Display using word descriptions might be depicted as in Figure 5.

Quantitative and Subjective Factors	Alternatives		
	A	B	C
Quantitative Analysis:			
Cost (in billions of $)	$34.1	$33.7	$39.4
Other quantitative factors:			
Response time (minutes)	3	13	17
Number of locations	15	9	22
Subjective Analysis:			
Deterrent Value	preferred	preferred least	2nd choice
Triad Advantage	2nd choice	preferred	preferred least
Technological Risk	preferred least	2nd choice	preferred
Public Reaction	preferred	preferred least	2nd choice

Figure 5: Initial Summary Display of CFBM options

An initial summary display for the same decision but using index numbers is illustrated in Figure 6.

Quantitative and Subjective Factors	Alternatives		
	A	B	C
Quantitative Analysis:			
Cost (in billions of $)	$34.1	$33.7	$39.4
Other Quantitative Factors:			
Response time (minutes)	3	13	17
Number of locations	15	9	22
Subjective Analysis: (1 to 10)			
Deterrent Value	3	7	5
Triad Advantage	6	2	7
Technological Risk	6	5	4
Public Reaction	3	7	5

Figure 6: Initial Summary Display of CFBM options

Step Three: Weighting of Each Factor. The next step in the summary display, and one which cannot be overlooked, is to determine the relative importance of each factor listed. In most cases each factor does not has the same impact on the choice of alternatives. Judgment of the decision maker must be applied to determine the relative weight that should be assigned to each factor to show its importance to the decision.

In the great majority of cases, determining the "right" value for this weighting factor must be done intuitively by the decision maker. There is no mathematical process that can produce this estimate. It is strictly a subjective estimate, hopefully based on professional judgment. The relative importance can be expressed in either verbally or numerically. Figure 7 shows the words that might be used in assessing the weight of factors in a hypothetical ship construction decision.

Quantitative and Subjective Factors	Weight of Factor	Alternatives A	B	C
Quant. Analysis:				
Cost (in $ Bil)	important	$27	$18	$23
Other Quant. Factors:				
Nbr of shipyards	less imp.	3	4	6
Ship types	important	4	3	5
Subjective Analysis:				
Warfare Capability	important	preferred	less capable	2nd choice
Flexibility	very important	preferred	2nd choice	not good
EW / C3 / MOB	important	2nd choice	preferred	lacking

Figure 7: Weighted Summary Display of Ship Construction Costs

It may stretch the logic of the Decision Process to suggest that specific numbers could be estimated that would accurately show the relative importance of each item. However, with the assistance of the decision maker, an attempt could be made to quantify the importance of the various factors by using a numerical weighting to indicate their importance. In the Ship Construction example, it might be decided that the cost in the quantitative analysis was

"very important" and the decision maker could judge that 60% of the decision should be based on that factor. Other quantitative items and the factors in the subjective analysis could also be assigned values to account for the remaining 40%. Figure 8 is an example of using percentages as a weighting tool in the summary display. (This example also uses a rank ordering of alternatives for the evaluation of subjective factors.)

Quantitative and Subjective Factors	Weight of Factor	Alternatives A	B	C
Quant. Analysis:				
Cost (in $ Bil)	.50	$27	$18	$23
Other Quant. Factors:				
Nbr of shipyards	.05	3	4	6
Ship types	.10	4	3	5
Subjective Analysis:				
Warfare Capability	.10	1	3	2
Flexibility	.20	1	2	3
EW / C3 / MOB	.05	2	1	3

Figure 8: Weighted Summary Display of Ship Construction options

Whether any further quantification of the summary display is reasonable is open to debate. It might be suggested that one could now multiply the weighting factor by the index number and add everything up to get the correct answers. This can be done but might exceed the limits of objective quantification in the Decision Process unless done using some form of utility analysis.

It must be emphasized that the summary display, either the simple display of information or the weighted index numbers, will not necessarily provide a more accurate interpretation of the factors that affect the choice of alternatives. However, it is one way to be more explicit about the relative importance of both quantitative and subjective factors in order to establish the rank ordered preference of alternatives.

Step Four: Rank Ordering of Alternatives. When the summary display is complete, then the most critical interpretation must be made, the rank ordering of alternatives. Within the Summary

Display you have all important factors developed to this point; the alternatives, results of both the quantitative and subjective analyses, and an assessment of the relative importance of each factor. With the system objective clearly in mind, one must now rank the alternatives based on this information, exercising the judgment essential to the process.

Interpreting Other Elements in the Decision

While the summary display has been completed, there are three considerations which may not easily fit in the display but should be assessed before conclusions and recommendations are made.

Uncertainty and Risk. Because uncertainty is always involved in complex decisions, it is important that the decision maker assess its impact on the preferred alternatives. While uncertainty may be considered during sensitivity analysis, interpreting the desirability of alternatives must be done in full recognition of how uncertainty affects the accuracy of the cost and effectiveness of the choices. More importantly, the decision maker must assess the risks that are caused by these uncertainties and determine any negative impact of choosing the wrong alternatives.

Outside Influences on the Decision. While external factors that affect the system and the performance of various alternatives have already been considered in the subjective evaluation, there may also be other pressures outside the influence of the decision maker which affect how the decision is to be made. Congressional attitude, lobbyists and other influential groups, and even pressures from other services can put direct pressure on the decision maker's willingness to base the decision strictly on optimum use of available resources. It is appropriate to identify for the decision maker these influences so that he or she is aware of their potential to affect the use of the rational model.

Change in the Decision Criterion. To evaluate quantitative factors a criterion was used which either maximized effectiveness for a given cost or minimized cost for a desired level of effectiveness. This provided the decision maker with the means to measure alternatives using an optimizing decision rule. However, the decision maker may also want to know which alternatives would provide a more conservative position, those which avoid high risk alternatives. Likewise, it should be recognized that the decision may be made in a competitive situation. Whether it is competing for scarce Defense resources or the actual struggle of combat, the need to respond to the moves and reactions of competitors can influence the decision maker's choice of alternatives.

THE RESULTS OF INTERPRETATION

At this point in the Decision Process all of the factors have been identified, evaluated and interpreted. No further information should be introduced, although the process of iteration always provides the option to return to earlier phases. The results of interpretation should follow logically from the analyses in the form of conclusions and, if appropriate, recommendations.

Realizing that, unless the individual using the Decision Process is the actual decision maker, the choice of alternatives can only be made by the person having control over the resources. Often, however, the decision maker does ask that the analysis provide recommendations which can be considered for execution.

Conclusions

Conclusions are the final output of evaluation and interpretation. As indicated above, the essential guideline for conclusions is that they are fully substantiated by the analysis. To pull a conclusion out of thin air does nothing but destroy the credibility of the entire Decision Process. Although there are many types of statements that can be included in this summary activity, three outputs are essential.

Rank Ordered Preference for Alternatives. One conclusion that should be made at the end of the analytical process is the rank order in which alternatives are preferred. The ranking of alternatives is far more useful to the decision maker than just pointing out the best solution or concluding what the decision should be. It is valuable for the decision maker to know if the preferred choice dominates other choices or is only a marginal improvement. Knowing if any of the alternatives have qualifying conditions is also very useful. It may be necessary to point out that the preference for alternatives is based on very limited data or a very simplistic evaluation process.

Relationship to Objectives. One very significant conclusion that must be made is the degree to which one or more of the preferred alternatives meets the desired objectives. Conversely, if none of the alternatives achieve the objective, then the conclusion may be that there is a need for a change in objectives or an increase in resources.

Extent of Uncertainty and Risk. If appropriate, conclusions should identify any uncertainty and risk which surround the ordering of alternatives. Conclusions should be stated in such a way as to indicate how uncertainty affects the accuracy and success of

alternatives and what risks are inherent in choosing each alternative.

Recommendations.

If recommendations are appropriate to the decision situation, there are certain types of advice that are usually very helpful in guiding the actions of the decision maker. Some recommendations will pertain to the decision itself and others to the utility of the Decision Process.

The Preferred Course of Action. From the rank ordered list of alternatives it would be appropriate to recommend the course of action that, from the viewpoint of the decision maker, provides the best solution to the problem. If there are caveats or major assumptions involved in this choice, they should be clearly indicated. To recommend that no decision be made should be done with utmost caution. Frequently, the decision maker does not have this option available. If deferring a decision is recommended because no alternative achieves the objective, then so indicate. You then may want to identify objectives that could be achieved with the resources available.

The Need for Further Study. There is always a great temptation to recommend delaying the decision because of the need for further study. As pointed out before, analysis is never complete. There is always the need to reduce the uncertainties in the decision and to consider other contingencies or scenarios that may be pertinent to the selection of alternatives. Equally realistic is the fact that most decisions are time-constrained. Therefore, this recommendation should only be offered when the results of the Decision Process have not provided any feasible or useful means for differentiating between alternatives.

SUMMARY

The Interpretation Phase brings together all of the previous activities of the Decision Process. Several different activities are used in the interpreting process. We look back to the quantitative analysis and interpret what the numerical results really tell us. Are the relative differences in choices significant enough to overcome any uncertainty that might be in the data used? We combine the quantitative and subjective analyses in a Summary Display to place all relevant information in front of us at one time. We can see the impact of each factor on the various courses of action and also apply additional weight to those items which are most important to the decision. The end product of the Summary Display is a rank ordered preference for alternatives.

Conveying these results is the final step before the decision is made. Conclusions and recommendations are used to communicate the findings of the Decision Process to the decision maker (if we don't fill that role). Conclusions should clearly state the preference for alternatives and the extent uncertainty and risk affects the decision. Most importantly, a judgment must be made as to whether the objective will be achieved by one or more of the choices. Recommendations of the preferred alternative or the need for further study can be made if appropriate.

CHAPTER VIII

IMPLEMENTATION AND VERIFICATION

Throughout this book it has been emphasized that the Decision Process is iterative. During each phase we should ask reassessing questions. Is the problem still valid? Do we have the right objectives? Are the alternatives feasible? Is the body of data correct? Has the uncertainty surrounding the decision situation been resolved, and if so, have we made the right commitment of resources to the problem? Those questions should continue to be asked long after the choice is made. The decision is not the end of the process. There is still a lot of effort required to get the choice into operation and to be sure that what is carried out is consistent with the course of action chosen by the decision maker.

The Implementation and Verification Phase helps to track the decision as the commitment of resources unfolds into a potential solution to the problem. The decision maker's primary concerns during this phase are to control the resources applied to the choice so that a smooth, harmonious transition between the decision and the operational stage is achieved and to make sure the selected course of action is still capable of achieving the system objective. This is the implementation portion of the phase. Because this process of putting a major Defense resource allocation into action may continue over a long period of time, a formal method is needed for determining whether the objectives themselves have changed to the degree that resources must be reallocated. We must also test to see if the alternative performs according to plan. This activity is referred to as verification.

There are many examples of Defense decisions that have successfully used concepts of implementation and verification to bring major weapon systems on line. Among them are the Navy Polaris and Poseidon submarine programs, the Army Multiple Launch Rocket System (MLRS) and the Air Force F-16 fighter. Many DOD organizations continue to use the implementation methods developed in the Navy's strategic weapons program. Project control systems such as PERT (Program Evaluation Review Technique) have proven of great value in implementing complex decisions. Operational Test and Evaluation programs (OT&E), specifically designed to periodically perform statistical tests of systems and their objectives, have resulted in major corrections and reallocation of resources as new technologies emerge or as other key factors change. On the other

hand, there are many examples of decisions gone awry because steps to ensure successful implementation and verification were not actively followed.

WHAT IS IMPLEMENTATION AND VERIFICATION?

There is great temptation in any process to divide all activities into their simplest elements. However, the purpose and application of implementation and verification are so intertwined that it is not easy to separate their interaction during the process of making decisions. They will be discussed together throughout most of the chapter, only separating them temporarily in order to define each and describe the procedures involved.

Implementation

The transition period between the decision to make a major resource allocation and having a course of action in full operation is referred to as the period of implementation. However, the consideration of how a decision is implemented must begin long before the decision is made and will actually extend far into the full life cycle of the system. How then is implementation defined?

> IMPLEMENTATION IS THE PROCESS OF PLANNING FOR AND CONTROLLING THE EXECUTION OF A DECISION TO INSURE THAT IT ACHIEVES DESIRED OBJECTIVES.

There are three key elements that are essential to carry out this activity. The first is a plan, the identification of the tasks to be accomplished and the sequence and timing involved. The second necessary element is an organized group, with the assigned responsibility and authority for insuring that the decision is implemented according to the desired course of action and the objective. The final key element is an information system which will provide feedback on how well the alternative is working. This system should pinpoint areas for attention which may need corrective action.

Implementation of Defense decisions usually spans the Research and Development, Procurement and Operational stages of the life-cycle of a system as depicted on the next page. Typically, the first steps of the implementation process are conducted during the R&D portion of the system's life cycle. The need for implementing actions tend to peak as the momentum of procurement rapidly expands the number of activities to be controlled and then tapers off as the system moves into the long-term operational stage.

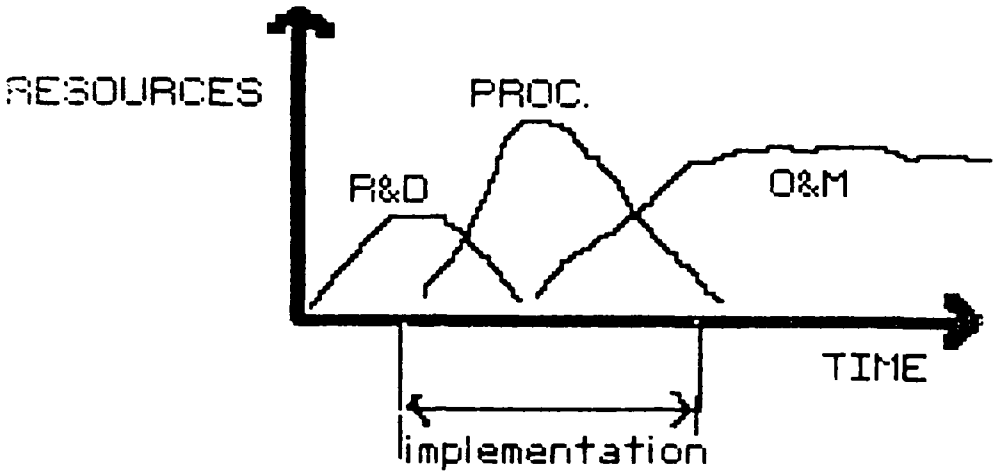

Figure 1: Implementation and the life cycle of a system

Verification

Hand-in-hand with implementation is the process of verification. Will the system objectives be met in the long run? Can we predict how the alternative will perform? These questions reflect the need for verification.

VERIFICATION IS THE SYSTEMATIC TESTING OF THE OBJECTIVE AND ALTERNATIVES TO INSURE THEY ARE CONSISTENT WITH EACH OTHER AND WITH THE DESIRES OF THE DECISION MAKER.

The process of verification can best be accomplished by embracing the following attributes. First of all, it should use scientific methods to test the selected alternative. This is usually a mixture of technical measurement combined with military judgment about the effectiveness as well as the cost of the alternative. As a second attribute, this verifying process should be conducted by an organization relatively free from "conflict of interest," bias toward the chosen alternative, or advocacy of another choice. Another necessary attribute is that verification be statistical in nature. To test how the systems functions with the selected course of action, it is usually feasible to test only a sample of the elements of the chosen alternative.

Verification is required in various stages of an alternative's progress from decision to operational use. Initially, individual elements are tested and the results integrated to predict effectiveness. As the alternative takes shape, tests of the first complete unit yield more definite indications of how well the system

objectives are being met. Finally, ongoing tests are made of operating units in the mature stage to insure both accurate and consistent performance. Solutions to defense problems that relate more to the human side of a decision situation can also be verified using techniques from the social sciences having a statistical base.

As in the case of implementation, verification spans several phases of a system life cycle. As indicated in Figure 2, the combination of verification and implementation activities cover the entire life cycle and overlap one another.

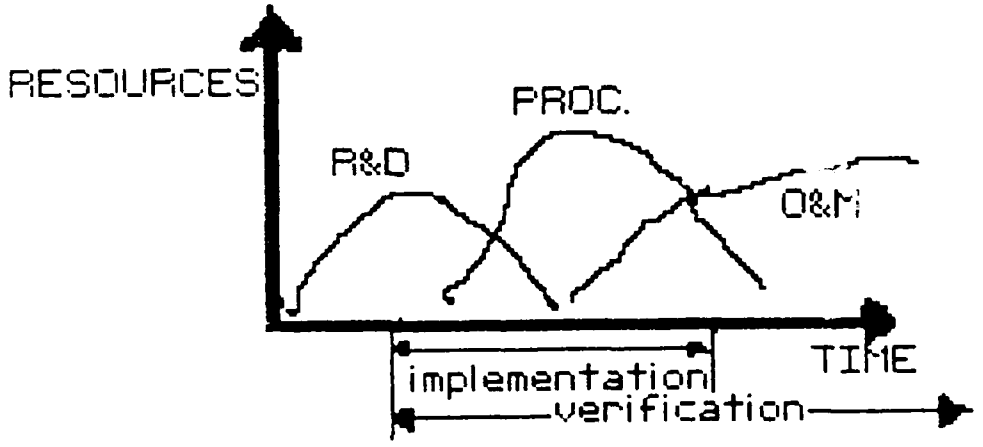

Figure 2: Where implementation and verification fit in the system's life cycle

UNDERLYING CONCEPTS

The Implementation and Verification Phase relies on several concepts and conditions to structure the procedures used. These ideas provide consistent guidelines so that the process can be applied across a broad range of decision situations.

Control as a Guiding Principle

Both activities of this phase rely on control as the primary means to carry out their correcting functions. Feedback mechanisms indicate whether the project is proceeding according to schedule and cost, and if any major technical difficulties are hindering the implementation process. Given this information, the decision maker can influence the outcome in an orderly and productive way. This management system can be used to exercise control over the expenditure of scarce resources.

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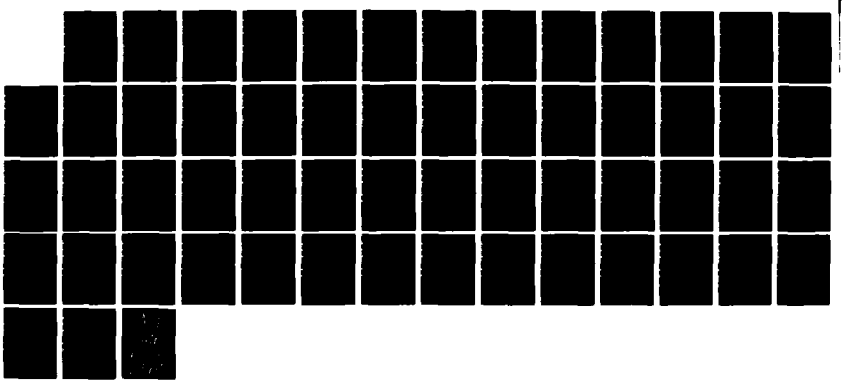

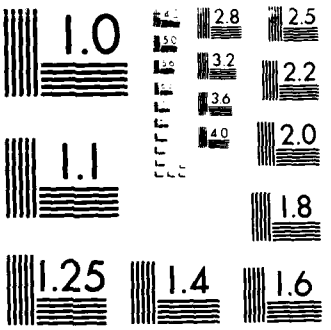

Many Roles for the Decision Maker

In the sequence of events that occur when dealing with major Defense issues, there are many different roles that a decision maker may be required to play.

The first involvement is usually as a planner, one who formulates objectives and evaluates alternatives long before any large commitment of resources is made. The main thrust of planning is to solve the problem up to the point where clear objectives have been stated and alternatives thoroughly evaluated. The next role of the decision maker might be implementing the decision as a program manager. The main effort here is to fully define the choice made in the planning stage and detail the steps and organizations required to get the alternative into operation. The decision maker's role shifts once again after the alternative has finally developed into a mature operating system. At this stage the concern is focused on making sure the objective is still the right one and is being met; the decision maker takes on the role of verifier and tester of the system operation.

The table below lists the three roles just described and the typical organization with major activities that fit these general descriptions. Often these decision making roles are carried out by entirely different individuals or organizations. In fact, it is rare that the requirement to be the planner, program manager and evaluator falls on the shoulders of one individual. Because of this the implementing and verifying stages of the decision often get neglected or carried out to different results than had been originally decided. As several individuals may undertake decision making responsibility, even more justification exists for tying in both implementation and verification to the overall decision process, insuring that the same life cycle concern given to the system is applied to carrying out the decision.

Decision-Making Roles	Typical Organizations
Decision planners	Resource Planners, Warfare specialist
Decision executors	Program managers, Operational forces
Decision verifiers and testers	Inspector General, Auditors

Table 1: Roles and typical organizations of decision makers

Timing of Implementation and Verification in the Decision Process

Considerations for implementation and verification need to be made as early as possible in the decision process. Formulation is not too early. Selection of the system objective, MOE and MOC, and alternatives should all be made with the requirements for implementation and verification in mind.

The individual who has thoroughly analyzed the decision may be the person most qualified to know how to implement the potential alternatives. The knowledge gained during the Decision Process should be used to develop broad guidelines for implementation. Secondly, the process of implementation and verification should be planned far ahead of execution to increase the likelihood of success. Finally, the decision maker will want to know how to get started once an alternative has been made. This includes knowing the general plan of attack, who will be the major participants in the implementation, and the general timetable for carrying out the decision.

IMPLEMENTATION: THE TRANSITION FROM DECISION TO REALITY

As we consider the procedures involved in implementation, a conceptual dividing line must be drawn at the point of decision. There are certain activities that should be a part of the implementation process prior to the decision being made and, certainly, a sizable set of procedures needed to accomplish the transition from decision to reality. Pre-decision consideration of implementation provides the decision maker with a potential plan for carrying out the course of action as well as a place to begin. The development of a tentative outline of implementing action is an excellent way to carry out this activity. Begin by listing all of the events and activities that must take place. Then make estimates of the sequence in which these events should happen and the timeliness requirements. Suggest possible organizational requirements and, finally, identify ways that control and feedback could be achieved. The level of detail should only be sufficient to determine that the course of action is possible.

Once the decision is actually made, implementation takes on a more vibrant character. With committed resources and a selected course of action, it is possible to direct and control these two elements toward the desired solution. Let us consider some of the more salient features of the implementation process by identifying four actions that should be taken: develop a plan that sets out the structure for implementing; organize personnel resources to put the solution into operation; establish a management information system for analyzing results; and, lastly, control progress toward successful implementation.

A Plan for Implementation: The Management Control System

The first activity in implementation must be to develop a plan or management control system. Although this roadmap for carrying out the decision will continue to evolve throughout the life of the system, the initial effort is the most critical part. The types of plans that could be used are far too numerous to list. They range from very informal, unformated outlines to highly technical and computerized programs requiring constant update. Two typical systems are the POA&M and the PERT network. Patterned after the Gantt chart which was first used in 1918, the Plan of Attack and Milestones is an easy-to-use format which requires no specialized training. To prepare a POA&M we only need to describe the project in terms of the activities to be completed, a time and quality of performance schedule for each task, and the sequence in which the events must occur. These, in essence, are the essential characteristics of any implementing plan. Program Evaluation and Review Technique has these same characteristics but is more useful in the implementation of very large systems . It uses the technique of networking, where the flow of interacting activities resulting in a finished product are all depicted against a horizontal time line.

Organize to Achieve the Solution

Whatever the decision, people and organizations must be focused in the direction which will produce the desired results. Who will do the contracting? Who will monitor the construction? Who will oversee and integrate the training? Who will monitor progress? Who is missing that we need to do the job? We need to combine all of these "who's" to form some type of implementation organization. They may be people functioning in an existing department or brought together for the unique task at hand (the underlying concept of Project Management). The essential point is that they are identified and assigned both responsibility and authority to implement the decision.

Establish a Management Information System

Carrying out complex Defense decisions often requires a multitude of tasks by many organizations. A management information system (MIS)is absolutely essential to this effort. In fact, the mere notion that such a tracking system exists often provides the impetus for becoming more involved in the the process of implementation. What does a MIS do? The system may utilize computer hardware and software, management and decision models, and a data base. There are many formats for management information systems that are designed to aid managers. The following list of qualities are generic to most of these systems:

A computer supported man/machine system. It is possible to generate a data base without a computer involved, but it is often

the power of the computer that makes a management information system successful. This does not eliminate the need for the man/machine relationship. For many implementing actions, it is the combined efforts of the computer and the "human interpreter" that enables problems to be identified and control to be exercised.

A system with both data base and integrated processing. The key to a good MIS is not only ready storage of and access to data, but the capability to process information so that it can be used in a variety of management applications.

Fully supports ongoing operations. A good MIS must be able to handle the events and activities of implementation as they occur. The decision maker cannot stop the process of putting a system into operation so that data can be collected. We look for "online" data collection and inquiry as well as rapid updating of the data base.

A harmonious interface with management control systems. The management information system must be compatible with the implementation plan or management control system. In addition to aiding in all general management tasks, this will allow the MIS to be specifically used in the control process of measuring actual performance with planned or standard performance and adjusting accordingly.

Monitor Progress Towards Implementation

After the implementation plan has been designed and tested, the manpower organized and a management information system established, we are ready for the final implementation activity. We will use this entire package to monitor the progress of implementation and exercise control over the resources being expended. Three critical factors require monitoring: the timing of scheduled events, the level of performance of the system, and the costs being incurred. The current status of each of these factors will be compared against the established system objective and the selected course of action and corrective action taken if needed. Frequently, trade-offs between schedule, performance and cost will have to be made. The management control system is the key tool to accomplish this adjustment of critical factors in the implementation process. Implementation is hard to accomplish regardless of what types of major resource decisions are to be made. Being systematic and trying to control the process is imperative if a course of action is to be successfully put into operation.

VERIFICATION: LIFE CYCLE MEASURING OF SYSTEM PERFORMANCE AND COST

Whatever the method chosen, the purpose of verification is to systematically check on the attainment of system objectives and to

see if any new information about the decision situation warrants modification to either the alternatives or its objectives. Checking on the system objective, and seeing whether there are better or less costly alternatives to solve the problems are essential outcomes of the verification portion of this phase. The emphasis will be on what kinds of testing can be done and who should do the verifying.

Verification of defense decisions, if properly done during peacetime, can be reasonable predictors of the eventual wartime consequences of the choices made.

How we Can Verify Objectives and Alternatives

Several methods are available to DOD managers to verify objectives and the alternatives designed to achieve them. It is important that appropriate ones are built into the overall process of implementation and control.

Sampling. Statistical sampling provides a means of verifying whether an alternative meets objectives without disrupting all of the elements of an alternative. The question of sample size and confidence in results does leave the decision maker with the problem of whether to accept or reject the sample as a valid indication of performance, but this can be overcome with good statistical practices. Quality assurance techniques and weapon system testing both use some variety of sampling.

Audits. Inspector General and audit teams can provide highly professional and potentially unbiased ways to verify many alternatives. Inspector Generals are able to verify effective operations using a variety of techniques such as testing, correlation with standards, simulated activities and interrogation. Their inspections have normally resulted in substantial verification of operational attainment of objectives.

Simulations. When real operational tests are impossible or when verifying the adequacy of an alternative depends on some future uncontrollable event, then simulation is a good way to verify the estimate of system performance.

Exercises. Exercises normally include tests of tactical alternatives to verify if they are feasible ways to conduct combat operations. Conducting regularly scheduled exercises also give decision makers evidence that the choice will be able to attain objectives over the life of the system.

Who Should Verify Defense Decisions

It is a generally accepted principle that those who spend the money should not be the ones who audit the books. This idea is equally true when it comes to verifying Defense decisions. Even if

the functions of implementation and verification are split and moved far enough apart to quell any conflict of interest claim, there still may be some vestige of common organizational interest that could cloud the results. This is where independent evaluation plays a very important role.

The point is that some distance is necessary between spender and verifier to get unbiased results. But it is also true that some linkage will probably remain because both institutions are involved in the same decision process, use common data bases and are usually responding to a single decision maker. If the organizational distance between the decision and verification is too far, it is difficult for the verifier to find out what's going on. His degree of expertise or knowledge about the way the system should operate is penalized by being separated from those who are responsible for the decision.

SUMMARY

In this chapter we have examined what should be done in the way of implementation and verification both before and after a decision is made. Implementation, the transition between decision and an operating system, has four main activities: setting up a plan on how to achieve the objective, organizing resources to do the job, developing a usable management information system and monitoring the process toward full operation of the system. Verification, the measuring of system benefit and cost, must begin early in the Decision Process and continue through implementation. It is important to determine who is to be the verifier of the decision, decide what to do with the results and utilize the information that statistical analysis provides.

CHAPTER IX

THE COST OF DEFENSE ALTERNATIVES

To make informed and reasonable decisions on Defense resource allocations, it is important to consider the cost of each course of action. There are times when cost may not be the dominant factor in a Defense decision such as in operational or combat situations. In peacetime costs are almost always a major, and often the primary concern when we choose between alternatives. To give an overview of cost concepts we will look at four topics: What does the term cost mean? What types of cost should be identified in the decisions we make? What are the sources of cost estimates? How can costs be used in the Decision Process and in following up on these decisions?

There are two important reasons for understanding these principles. First, a knowledge of cost concepts will help one fully investigate the cost ramifications of choices available in a decision. Second, most of these cost terms and procedures are used extensively throughout DOD. Learning their meaning and how to use them is essential to communicating the rationale of a decision to others. More than a few hours have been wasted because two different agencies didn't have a common understanding of cost terms or a cost analysis procedure.

THE MEANING OF COST

"Like so many common words, cost is used differently in different contexts, differently by different people, and usually in vague terms." [1] We must carefully define the term. Let us do this in general terms, and then look at some common cost categories.

The dictionary refers to cost as an amount paid or required for a purchase; a loss or penalty; a detriment. This definition is useful for daily activity but not particularly helpful here. The DOD directive that outlines policy guidance on Cost Analysis does not define cost per se although it implies that cost refers to the

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1 E.S. Quade, "Costs" in Analysis for Public Decisions, Elsevier, New York, 1975, p. 124.

resources required to achieve stated objectives. 2 The Appendices of both the Air Force and Navy's Economic Analysis handbooks do, however, share a common definition of cost: "The value of things used up or expended in producing a good or a service. Also, whatever must be given up in order to adopt a course of action." 3 The essence of the meaning of cost is that it represents what one must give up to get what is wanted. In the context of decision making, let us define the word in this way:

COSTS REPRESENT RESOURCES TO BE CONSUMED AND/OR OTHER OPPORTUNITIES FOREGONE BY THE CHOICE OF AN ALTERNATIVE.

TYPES OF COSTS

More precise meanings of cost are dependent on other modifying words which are linked with cost to denote a specific type. For example, the Navy Economic Analysis Handbook lists three pages of definitions using cost combined with other words. The definitions include everything from actual cost to variable cost. 4 It is important to know some of the more frequently used categories of cost so one can recognize their meaning in various forms and use all pertinent information to compare alternatives. This will prove valuable when communicating the quantitative reasoning of the Decision Process to others. What follows is a brief discussion of some of the most common and useful ways in which cost can be expressed.

Dollar Costs

For those who think primarily in terms of real-life tangible resources, i.e., people, fuel, aircraft or ships, it is obvious that dollar costs are neither a complete nor an accurate measure of how much something is worth. However, just because "dollars aren't everything," we cannot treat them lightly or ignore this type of

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2 Assistant SECDEF (Comptroller), Department of Defense Instruction 7041.3 of 18 October 1972, "Economic Analysis and Program Evaluation for Resource Management."

3 Lorraine Morris, Economic Analysis Procedures Handbook (AF Pamphlet 178-8) HQ USAF, 19 May 1981, p. A2-1 and Navy Economic Analysis Handbook, (NAVFAC P-442), Naval Facilities Command, July 1980, p. G-6.

4 NAVFAC P-442, p. G-6 to G-8.

cost. There are various ways that dollar costs can be expressed. The four different categories we shall discuss are all related to the idea that time affects the value of money: life cycle costs, current and constant dollar costs, and present value costs.

Life Cycle Costs. The concept of life cycle costs represents an appreciation for the total resources consumed over the entire life span of a system or project. In Defense, the normal components of the life cycle costs for a weapon system are research and development (R&D), investment and procurement, and operations and maintenance (O&M) costs. Usually, the dollar value of life cycle costs would vary from year to year, as shown in Figure 1. The dollar value of these three annual components are added together to equal life cycle costs. The life cycle cost curve is an annual total of the three component costs.

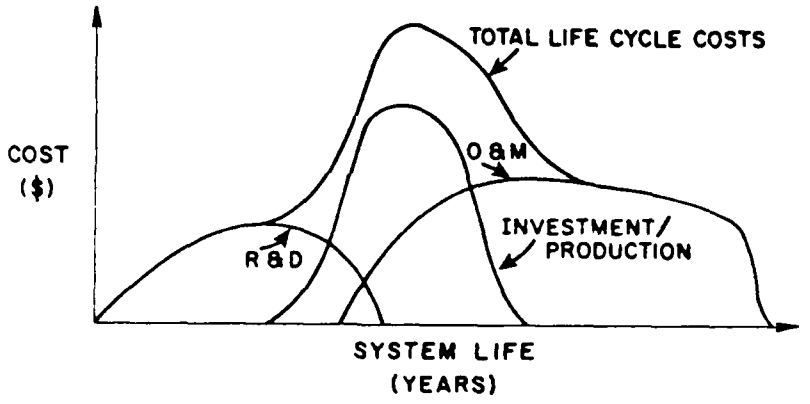

Figure 1: The Life Cycle Costs for a weapon system

Sometimes life cycle costs can be offset by monetary benefits. For example, consider an alternative that proposes the leasing of a machine in lieu of continuing operations with an old, worn out government-owned machine. If this alternative was chosen, we might foresee a cash inflow for the government by the (salvage) sale of the old machine. Similarly, it may be estimated that an alternative under consideration in a decision will have some terminal or residual value at the end of its mission life. An economic analysis of the cost of such an alternative should reduce life cycle costs by these monetary benefits. In summary, life cycle costs, offset as they might be by any benefits, are a way to describe the total amount of resources required for an alternative. Life cycle costs

should be described in two dimensions, the sum of the component costs (R&D, Procurement, O&M) and the cumulative costs over time.

Current Dollars: Costs and prices change over time. A purchasing price that reflects the impact of the rise in general cost of living (inflation) is measured in current dollars. For example, if it cost $1000 for a widget in 1981 Current Dollars and there was a 10% annual increase in prices, one would pay $1100 a year later, using 1982 current dollars. The costs used in the Five Year Defense Plan (FYDP) are expressed in estimates of current dollars. In the 1971 FYDP an Oliver Hazard Perry class frigate might have cost $65 million (1973 current dollars) in 1973 and the same ship cost $100 million in 1976 (1976 current dollars), the difference reflecting the inflation from '73 to '76. In that current dollars represent the documented amount of a past cost, or the estimate of expected future expense, they provide a useful and meaningful way to compare values in the same timeframe. However, in the evaluation of alternatives, the use of current dollars is severely limited. This is because one cannot compare current dollar costs from different years because they represent different values. This fact is often overlooked when the media reports that the Defense budget is the highest in history.

Constant Dollars. We can compare the dollar costs for different years by expressing them in constant dollars. Constant dollars are a way of stating costs with the price change due to inflation removed. They reflect constant purchasing power and are stated in dollars that have the same value as that of an arbitrarily selected "base" year. Thus, if a widget actually cost $1000 in 1981, the same widget would also be valued at $1000 in 1982 if we were measuring cost in 1981 constant dollars. Likewise, the cost of the frigate procured in 1976 would be expressed as $65 million 1973 constant dollars if its real value had not increased since 1973. More than likely, however, the constant dollar cost of that frigate did increase from 1973 to 1976 because of factors other than inflation, such as improved quality or more capability. And herein lies the benefit of using constant dollars. If the frigate's cost was $75M in 1976 (in constant 1973 dollars) , we can see that the real, non-inflation increase in the cost of the ship between 1973 and 1976 was $75 million minus $65 million, or $10M. It can be seen that constant dollars provide an excellent common measure of cost that can be easily compared, regardless of the year within which the cost occurs. 5

Present Value Costs. Few will argue with the idea that there is a time value to money. Bickner puts forth a very clear

5 NAVFAC P-442 offers many exercises and further discussion covering the use of these two concepts of dollar cost.

explanation of why we must account for the difference in the value of cost because of the passing of time.

> Time is valuable. Indeed, few things are more valuable, whether we are thinking about our personal lives, or a military campaign, or business investments, or farming, or the development of new military capabilities, or national economic and social programs. And yet the value of time is often forgotten, particularly whenever someone compares dollar expenditures this year with those of next year and the year after, as if all of the dollars were equal...They are not. No military officer would suggest that a reserve infantry battalion arriving at the front line next week is equivalent to a battalion arriving today. No shipbuilding contractor would admit that construction materials arriving next month are equivalent to those arriving this week. Resources on hand today are usually worth more than identical resources deliverable tomorrow. Consequently, dollars with which we can buy resources today are worth more than dollars available tomorrow. Thus, before we can meaningfully add together dollars spent or received in different periods, we must discount future dollars, for they are worth less than (today's) dollars. 6

By discounting future costs, we reduce them to a "present value," an expression that reflects their worth now when the decision is being made. The procedure for discounting is simple, but the choice of a discount rate can be very difficult. Although the reason for computing present value is certainly different, the discounting procedure is simply the reverse of that for compounding interest.

Let's look at this time dimension of the life cycle costs we discussed earlier. Applying present value comparison would mean that the constant dollar estimated to be spent for O&M in 10 years would be valued considerably less in the decision than the constant dollar cost incurred this year for R&D or procurement. Keep clearly in mind, however, that computing the present value of future costs in no way changes the actual outlay of money in the future. It only translates, for the purpose of making a decision, all costs into one common value so that they can be fairly compared. What discount rate should be applied to future dollars so that all costs can be sensibly compared in one common timeframe? 7 This question will not

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6 Bickner, Concepts of Economic Costs, p. 51.

7 It is important to realize that the present value calculation should be based on constant dollar estimates, cost measures which have the effect of inflation removed. Uninformed executives often think that we discount because of this rise in

be debated here, although it is an issue the decision maker must deal with if the costs of possible alternatives differ over time. Current DOD policy, based on guidance from Office of Management and Budget circular A-94, is to use a 10% rate. 8

Other Costs

Dollars are not the only way to measure cost. Other costs can often be used to make decisions. For example, ships burn fuel, expend ordnance and need people to man them. Analysis can convert all of these into dollar values, but in a combat situation these resources are a more direct and appropriate measure of cost. Many times these other costs need to be recognized in peacetime decision making. The berth space a ship takes up along side a pier, the deck space used on a carrier or the minutes on station for a fighter aircraft are all costs which dollars cannot really describe accurately. To apply the Decision Process one may need to use a cost which isn't measured in dollars to compare the alternatives.

Relevant Costs

We need to distinguish between the costs that are pertinent to the decision and those that are not. For decisions yet to be made, relevant costs are those that distinguish among alternatives and are within the purview of the decision maker. Relevant costs lie in the future, not in the past. Suppose, for example, that we want to build a park for Navy people and their dependents. One alternative is to develop the park on land acquired several years ago for the purposes of building a supply center that was never constructed. In this decision, the cost of purchasing that land is no longer a relevant factor. Costs that have already been incurred are costs resulting from past decisions. 9 It is implied that only costs that are different from one alternative to the next are relevant. This is only partially true. In this example the cost of recreational equipment might be the same for all alternatives. This cost would not serve to distinguish between the choices and would probably not be a factor that contributed to making the decision. This notion

prices and that we must inflate constant dollars before we discount them. That's not the case. As discussed earlier, we discount primarily to account for the value money has over time. Using constant dollars allows the issue of inflation to be set aside.

8 DOD Instruction 7041, p. 13, 14. For those who might like to pursue present value further, descriptions and practical examples of its use are well detailed in the Navy and Air Force Economic Analysis Handbooks cited in 3 above.

9 Adapted from Quade, "Costs," p. 129.

is a bit misleading because some common costs may need to be considered to clarify the consequences of the decision itself. If we were on a constrained budget, equipment costs which were common to all options would necessarily impact on the ability to choose any of the alternatives. However, to evaluate alternatives we need to differentiate among the alternatives, not look at the common costs.

Relevant cost must be related to to the span of influence of the decision maker. By considering only those costs which fall under the control of the decision maker, we can put limits on the search for cost information. If the Base Commander is going to make the decision on the park location, he does not need not look past the resources he controls.

External Costs

External costs exist when all of the costs involved in a decision do not come from the resources controlled by the decision maker. Quade summarizes the concept well.

> Fairly standard examples of external costs include the adverse affects on flora and fauna caused by cutting down trees in a forest or the increase in the mosquito population by the creation of artificial lakes and other ecological repercussions that ultimately affect the welfare of the people. The offense given by the erection of a building which interferes with television reception is a cost to those who must buy a special antenna.....The number of external costs in the real world are virtually unlimited. 10

In Defense decision making, we can distinguish between what is internal and what is external by looking at the system. Viewing the relationship of the system to its environment may identify some of the external costs.

Let's consider a carrier-based logistics system. Its objective is to support a Carrier Battle Group (CVBG) with personnel and light weight cargo delivery. Internal costs for this system would include all the resources used while achieving that objective: personnel, fuel, aircraft, spare parts, and so forth. Suppose one of the proposed alternatives for this system included the use of an aircraft normally employed in the Anti-Submarine Warfare (ASW) mission. Choosing this alternative would incur an external cost in the form of the loss of some ASW capability. Would this external cost be relevant to the decision? Yes, it would be if the decision

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10 Quade, "Costs," p. 130.

maker were the CVBG Commander, because both the logistics and ASW system fall under his purview.

This distinction between costs that are either internal or external to the decision can be helpful in several ways. By looking at the external world, our attention may be drawn to pertinent costs that might be otherwise overlooked. We should consider the consequences of our decisions on others. Categorizing costs by their internal or external location may also be helpful in judging the relative importance of the costs. Generally, we would view the impact of the primary resources consumed by a system (the internal costs) to be greater than those external costs which are still pertinent to the decision. In some cases, it is helpful to identify significant costs that are beyond the boundary of the decision maker's concern. Often the recognition of external costs, even though not involved in the cost computations, will point out difficulties that should be expected in implementing decisions. An excellent example is the external costs that the Navy experienced in trying to bury submarine communications antennas in the Midwest.

SOURCES OF COST ESTIMATES

The defense organization is well staffed to project internal dollar costs. Cost analysts and budgeteers exist at all levels of the defense establishment. Each of the services have cost estimating offices. Project managers for specific weapon systems also assemble estimates of the components of life cycle costs. Nevertheless the accurate projection of costs continues to be a problem, especially in the procurement of weapon systems and in the analyses of other large and complex programs. Because of this, special estimating methodologies have been developed. There are at least four basic approaches to estimating the costs of defense projects. These are the industrial engineering, parametric, analogy, and the top down methods. An awareness of the general principles of these methods, along with some pitfalls and perspectives, can help one understand their use. [1]

Industrial Engineering Method. Industrial engineering is referred to as the bottom up or grass roots approach. It consists of a consolidation of estimates from various separate work segments into a total project estimate. A familiar example is that of a civil engineer estimating the cost of a new maintenance facility. He may estimate the construction cost as being equal to the sum of those from the structural, electrical, plumbing, heating and other

[1] The discussion of cost estimating methods is adapted from NAVFAC P-442 and Eugene L. Scott's "The Cost Growth Phenomenon," National Contract Management Journal, Winter 1983.

aspects of the project. Each sub-estimate may have numerous labor, materials, and equipment components.

The bottom up method represents the most thorough approach, with estimates from experts on all details. It is also specifically tailored to individual project requirements. However, industrial engineering can be overly pessimistic because of redundant contingencies in each estimating package. It can also result in underestimates because of items of work omitted, unrealistic assumptions or inadequate allowances for unexpected conditions or schedule delays. Another drawback is that this grass roots type of estimate is not easily compiled on short notice.

Parametric Cost Estimating. In this method, the total cost of alternatives is based on relationships to parameters or characteristic elements. Examples include dollars per square foot for building a house, and dollars per ton of displacement for a nuclear powered submarine. In other words, a functional relationship must be established between the total cost of an alternative and the various characteristics or parameters of the system. The aim of this type of cost analysis is to develop a valid Cost Estimated Relationship (CER).

Parametric cost estimating is the most commonly used method in DOD for establishing the cost of an alternative. Its primary advantage is that it represents comparison with realistic, historical experience. On the negative side, parametric costing does tend to be overly pessimistic because of failure to take into account improvements or lessons learned from past mistakes. Parametric cost estimating is also difficult to tailor to individual circumstances or accommodate differences from the comparison data.

Analogy Method. When more formal techniques cannot be applied because detailed data does not exist, the analogy method may be used. This approach estimates cost by making direct comparisons with historical information on similar existing systems or their components. For example, land parcels could be priced based on the sales of similar plots. Many low cost defense equipments are costed by the analogy method as are ship operating and support expenses.16 A major caution in using the analogy method is that it is basically a judgment process and, as a consequence, requires a considerable amount of experience and expertise if it is to be done successfully.

Top Down Approach. Similar to the analogy method, top down estimates are made by a general assessment of what the project should cost. They are based primarily on funding availability. This method can be useful because it attempts to assign value based on what is considered acceptable at a particular time period. However, what an alternative should cost can represent more wishful thinking than a rational cost estimate. In fact, the top down approach tends to be overly optimistic because of ignoring details of specific requirements as well as potential difficulties. The

Naval Material Command has used this estimating approach for the AEGIS weapon system, the latest ship sonar, and the air-to-air missile used on the F-14 fighter. 12

A Caution on Estimating. The preferred approach to cost estimating would be to combine several, if not all, of these methods. But, doing this becomes a costly process. A second point to remember is that the data generated are only estimates, not certain projections of the actual costs of alternatives. They are usually the results of statistical analyses, and therefore should be viewed as approximations rather than hard, specific values. Finally, all of these cost estimating devices tend, by design, to overlook the other kinds of costs that might be a far more relevant way to measure the resources used by a choice.

THE USE OF COST TO MAKE DECISIONS

There are many ways that the concepts of cost are applied in the process of deciding about defense resources. Let's discuss how costs should be treated in three different parts of the overall decision: in the analysis leading to a decision, when implementing the selected course of action, and throughout the time we are verifying how well the decision is meeting the objective.

Economic Analysis

The first area where cost is applied to decision making is in the analytical portion of the task, where objectives are defined and alternatives are evaluated. The Assistant Secretary of Defense (Comptroller) considers economic analysis as a systematic approach to the problem of choosing how to employ scarce resources and an investigation of the full implications of achieving a given objective. It is DOD policy that an economic analysis is required for proposals which involve two or more options, and should consider costs, schedule and performance. 13

The Decision Process fits the description of economic analysis well. Rightly so, as both processes have nearly the same set of characteristics. But regardless of how the overall process might be described, Economic Analysis or Decision Process, cost is used in every phase.

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12 These cost estimating examples were taken from the DOD Cost Analysis Symposium Service Meeting, 26 June 1984

13 DOD Instruction 7041.3, p. 2, 3.

Cost is a large part of the equation of economic analysis, providing half of the capability to measure alternatives. The earlier discussion of cost categories should prove to be a helpful guide as the costs of alternatives are developed in the analysis. Total relevant life cycle costs, offset as they might be by any benefits, should be considered. Other costs obviously should be explored. This includes those not measured in dollars and those beyond the immediate system of concern but still of interest to the decision maker.

At this analysis stage of the decision, comparison of dollar costs should use constant dollars. Inflation should be factored out of the evaluation if we think that general price increases will affect all alternatives equally. If we have reason to believe that any particular component cost of an alternative will experience unusual price increases, we would want to explicitly account for such a difference in our analysis. This could be done by escalating those, and only those, peculiar costs. Finally, if the dollar costs of alternatives differ with respect to their dollar outlay over time, their constant dollar cost streams should be reduced to their present value for comparison.

Other types of costs may require special executive-level attention. This is especially true because of the institutional emphasis which is placed on those measured in dollars. Evaluation using other kinds of costs will probably be more difficult for two reasons. Data will be harder to find than dollar costs, as nearly all organizations have specific rules requiring record keeping of the latter. Secondly, many other types of costs tend to involve a subjective assessment as well as a quantitative one. This should include a judgment of how important the value of these costs are with respect to those measured in monetary terms.

Budgeting

Decisions about defense resources are initially implemented by inclusion in the Budget. It should be recognized that costs receive significantly different treatment in budgeting than they do in analysis.

Budgeting in the context of the DOD Planning, Programming and Budgeting System involves tying mission needs to resource requirements. It is a process that produces a Five-Year Defense Plan, with proposed programs translated into terms of dollars to be spent in the future. Budget dollars reflect the value that items will have in the year they are expected to be acquired or used. Therefore, inflation must be included and the values are expressed in what we earlier described as current dollars, although the more technically correct term is budget dollars. One can also hear them referred to as "then year" dollars, a term frequently used in the Pentagon.

For example, if in 1984 we are budgeting for 1989, we will somehow have to take into account expected price increases between now and then. We want to do this with as much foresight as possible. "Clearly defense budgets eroded by unforeseen inflation will fall short of their goals, just as an economy weakened by too much inflation will lose its productive strength." 14 There are offices in the DOD that routinely provide the guidance for how much inflation to include. So, budgeting involves estimating costs and then escalating those costs to then year or budget dollars in accordance with the latest DOD guidance, the entire process often being called "costing" by those in the business. 15

Program Evaluation

The extension of the defense process that deals with following up on decisions is referred to as Program Evaluation. According to DOD Instruction 7041.3, the bible of Defense economic analysis, "Program Evaluation is economic analysis of on-going actions...." 16

In this later stage of the decision process we are verifying the decision by asking many questions. Are we satisfied? Are the objectives being achieved as the result of our decision? At what cost are decisions being translated into operational reality? Again, as in the analysis of proposed programs, all relevant costs must be evaluated. This will require a thorough tracking effort. However, unlike pre-decision analysis, this verification of decisions uses actual cost data which have been collected. Defacto current dollar outlays should be tallied and reduced to constant dollars so they can be measured in common terms for evaluation. Costs measured in other than dollars and external costs should likewise be used to verify that alternatives are being carried out as decided.

In sum, we find that similar cost estimates are used differently in the analysis of alternatives than they are in budgeting. The decision process leading to a choice should compare relevant constant dollar costs, perhaps in present value terms. Budgeting applies inflation factors to cost estimates and expresses costs in current dollar terms. Post decision evaluation is based on the actual costs experienced.

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14 Jack R. Borsting, "Shaping the Defense Budget: The Role of Economic Analysis," Defense Management Journal, Second Quarter 1983.

15 OMB, OSD and NAVCOMPT pricing guidance is typically reviewed and updated twice a year (Source: CNO Memo POM 86-9 27 Oct 1983).

16 DOD Instruction 7041.3, p. 3.

SUMMARY

Costs are indeed the negative consequences of decisions. They represent what must be given up to get what is wanted. The Decision Process seeks to identify, measure and then evaluate the benefits foregone by choosing one course of action, one policy or program, rather than another. When we use dollars to estimate costs we are attempting to identify required resources as well as the alternatives they represent. These dollar costs can be described as life-cycle costs, current or constant dollar costs, and present value costs. There are other types of cost that can be used to measure the resources used in decisions, particularly in operational environments. The key sorting tool for cost is relevance. Does the cost help to differentiate between alternatives?

We can obtain cost estimates from a wide variety of sources, each having certain strengths and weaknesses. As the decision grows in size and complexity, we are more inclined to use the more generalized type of estimates, such as the Analogy Method or the Top Down Approach. Cost is used from the start to the finish of the Decision Process. Through the budget, it is the primary means to begin implementation of a decision. Then we use a broad range of Program Evaluation activities to verify that what has been decided will actually come to fruition.

CHAPTER X

A SUMMARY OF THE DECISION PROCESS

In working toward a clearer understanding of the Decision Process, one must develop expertise by applying the process to a wide range of real and hypothetical situations. He or she should also be aware of what can go wrong when doing analysis and begin to tailor the process to fit personal inclinations and capabilities. Through the analysis of a complete case this summary will provide an opportunity to improve one's capability to use a rational decision making process.

APPLYING THE DECISION PROCESS TO A COMPLEX DECISION

The case study to be used with this summary illustrates how to put together the five phases of the Decision Process and the many elements that make up each phase. It will also point out some variations that can occur because of the structure of the decision. One will be able to see how the iterative process is essential to the development of any decision as well as the requirement for active follow through once the choice is made. In reading the case, it will be obvious that much of the data has been simplified or excluded because of the limitations of space. However, the essential parts of the Decision Process are used to illustrate each of the concepts. The reader is encouraged to read the case study and to actually use the Decision Process to arrive at a solution before reading further.

AN ANALYSIS OF THE CASE "HOMEPORTING THE SAG"

The following analysis of the Homeporting case provides a complete summary of the Decision Process, as well as a guide for application to other decision situations. It is provided with two caveats. It is not possible to include all of the information developed, and thus, the responses have been abbreviated. It must also be understood that this analysis is not offered as the one right answer. The analysis is a very good one, but its "correctness" is very dependent on the assumptions made and the assessment of which factors are relevant. From the standpoint of

format, it fulfills the intent of the Decision Process. It is presented in "split" format, that is, the summary of the process is shown on the left side of the page and the responses to the case are found on the right side except where the answer requires the full page. It should be obvious from reading the analysis that it was arrived at in an iterative manner, this being the end product.

FORMULATION PHASE

In the Formulation Phase we will clarify the objectives, the issues of concern and generally structure and limit the decision to be made.

Element	Response
1. Define the Decision Situation. A condition where there is a gap between a present situation and a desired goal, and there are alternative means to close gap. May be perceived as a problem, unfilled requirement or an opportunity for adjustment or change.	"Due to overcrowding at existing ports and the need for strategic dispersal, the Navy is looking at three alternative homeports for the West Coast SAG. The task is to recommend the best alternative for the Navy, based on identified criteria, no later than 25 July 1985."
2. Determine Who Is the Decision Maker. The decision maker is the person who is responsible for, or more importantly, controls the resources that are involved in the decision. The analysis should reflect his or her viewpoint.	"SECNAV, based on recommendation by OP-04 and CNO."
3. Describe the System. The set of interrelated activities about which a decision is being made. Both the larger system and the external environment are important to the description.	"The Homeporting system is made up of land, facilities, utilities, housing, base/personnel support; with activities of ship movement, berthing, replenishment and repair. The higher system is Pacific fleet operations.
4. Identify the System Objective. What the system is intended to achieve	"Provide adequate support for the SAG in port (including berthing, utilities, ships services, housing, base/personnel support) while achieving strategic dispersal and proximity to the sea lines of communication."

Element	Response
5a. Establish a Measure of Cost. A scale or index which will be used in quantitative analysis to compare the resources used by various alternatives to accomplish the system objective. A variable, not a fixed value.	"Investment Dollars"
5b. Establish a Measure of Effectiveness. A scale or index which measures the output of the system. Used in the quantitative analysis to compare the effectiveness of alternatives in accomplishing the system objective. A variable, not a fixed value.	"Amount of support provided in various area of homeporting; land, ship berthing, utilities/ services, ship service, housing, base/personnel support, quality of life." 1
6a. List Key Factors. Factors identified in formulation which impact on the selection of alternatives, conduct of the analysis or implementation of the decision. Some should be evaluated during the Subjective Analysis.	"a. All ships should be berthed at the same site. b. Pier side mooring is preferred to nesting. c. Important prerequisites for port selection: community support, political support, and quality of life. d. Anti-nuclear activists are vocal in all three locations. e. Congressional support for SAG is strong in all three areas."
7. Make Assumptions. Statements which list uncertain but important data as factual for the purpose of the analytical process. They allow the Decision Process to continue where uncertainty exists. Assumptions will be tested later during Sensitivity Analysis.	"a. Cost information provided is accurate. b. Recurring costs will be the same for all alternatives. c. Nesting is acceptable berthing method.

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1 Because "support provided" cannot be measured by a single value, the MOE becomes a combination of several scales which measure each of the qualities that indicate support provided. This can only be done when we intend to fix effectiveness at specific levels and minimize the cost of alternatives.

Element	Response
	d. All alternatives can meet deadline. e. Army Corps of Engineers will not bear cost of dredging in Seattle (or anywhere else)."

SEARCH PHASE

This phase represents a research effort to find and describe alternatives that may meet objectives and close the gap in the decision situation. This means looking for and structuring the relevant data and relationships that help compare alternatives, especially with respect to their effectiveness and cost.

Element	Response
1. Identify Alternatives. A specific set of activities, components and interrelationships which may be selected by the decision maker to achieve the objective.	"a. Homeport the SAG in Long Beach, Ca. b. Homeport the SAG in San Francisco, Ca. c. Homeport the SAG in Seattle"
2. Collect and List Relevant Data. Those pieces of information that are pertinent to the decision because they will serve to distinguish among alternatives and are within the purview of the decision maker.	(See Figure 1 for display of relevant data.)

FIGURE 1

A. Effectiveness Data:

Item	Long Beach	San Francisco	Seattle
Port Data:	Not as protected or deep as others. Many obstructions. 7 nm to open ocean.	Best deepwater port on west coast. 12nm to open ocean. Commercial traffic will restrict movement.	Deep, well protected. Normal commercial traffic. 14nm to open ocean.

Item	Long Beach	San Francisco	Seattle
Proximity to SLOCs:	Farthest	Moderate	Closest
Proximity to training areas:	Closest	Moderate	Farthest
Berthing:	3500 feet	5200 feet	3200 feet

Note: All three alternative sites claim they meet basic stated requirements. Comments on specific benefits to be provided are displayed below along with the associated costs.

B. Cost Data (in millions of investment $):

Item	Long Beach		San Francisco		Seattle	
Land	$ 2.820	(17)	$ 0	(10)	$ 0	(1)
Berthing:						(2)
Piers:	$ 0	(18)	$ 0	(11)	$ 0	(3)
Dredge:	$ 9.200		$19.600		$46.075	(4)
Utilities:	$10.950	(19)	$14.200	(12)	$ 7.750	(5)
Ship Service:	$ 8.120	(20)	$ 6.000	(13)	$ 5.880	(6)
Housing:		(21)		(14)		
Renovations:			$ 9.800		$ 3.900	(7)
Barracks:	$ 7.870	(22)				
Base & Personnel Support:	$19.550	(23)	$53.400	(15)	$18.400	(8)
Quality of Life:	$?	(24)	$?	(16)	$?	(9)

Notes to above data:
(1) State will give Navy 50 acres.
(2) Two former coal piers.
(3) State to pay $2.310 M for repairs.
(4) Army Corps of Engineers may pay for dredging (unlikely).
(5) State to pay $3.320 M.
(6) Estimate for new (IMA) maintenance building.
(7) Housing and barracks must be built. To be subsidized by State.
(8) 17 acres paved parking, public works center, recreation facilities, administrative and medical space. All need renovating.
(9) Infrastructure exists to support SAG, cost to rehab unknown. Easy access to base from community.
(10) California will return 50 acres to Navy.
(11) San Francisco to pay for construction of new piers.
(12) Must extend water system; new electric, sewage and steam.

(13) Needs maintenance and warehouse facilities.
(14) Site includes 100-150 units of government quarters at Hunter's Point. City to build moderate income apartments for Navy personnel. UEPH/BOQ to be renovated at no cost to Navy.
(15) Gym, parking and chapel available. Administration and hospital require renovation.
(16) State and City will "try" to make area safe, good place to live. Costs unknown.
(17) 16.5 acres will be bought;31 acres returned to Navy at no cost.
(18) Navy owns pier but now leases to Long Beach Port Authority.
(19) Navy to improve facilities.
(20) Improvements to existing facilities needed.
(21) No government housing available. Affordable housing allegedly available within one hour commuting time.
(22) Barracks improvements.
(23) Public works center, recreation, administrative and medical facilities need improvements.
(24) Communities are safe. Community reaction highly favorable.

C. External Data:
1. Political support is favorable at all three sites.
2. Community support:
a. Pro-nuclear freeze activists at all three sites.
b. Appear to be mixed emotions in San Francisco.

EVALUATION PHASE

In the Evaluation Phase we compare alternative solutions. We do this in two ways. The quantitative analysis is where we evaluate the choices, insofar as we can measure costs and effectiveness in common terms. We then use a subjective analysis to account for the remaining relevant factors (both quantitative and non-quantitative) that bear on the decision.

Quantitative Analysis

This involves using a criterion and models to establish a quantitative preference among alternatives. We also test the sensitivity of preferred choices to changes in the assumptions or data estimates.

Element	Response
1. State Criterion for Quantitative Analysis. A statement defining the relationship between effectiveness and cost that serves as a decision rule for quantitative ranking of alternatives. One of two kinds of criteria are generally used in Defense Analysis:	"Minimize Investment Cost to provide adequate homeporting support to the SAG." * * Adequate as defined by the required level in each of the areas outlined in the memo from CINC, U.S. Pacific Fleet.

Element	Response
a. Fixed Effectiveness. This involves establishing a point on the effectiveness scale (MOE) and comparing the cost of alternatives achieve this level. We rank the alternatives which meet the desired desired effectiveness by cost.	(kind of criterion used in this quantitative analysis)
b. Fixed Cost. We establish a point on the cost scale (MOC) and compare the alternatives based on effectiveness. We rank the alternatives that meet cost constraints by effectiveness.	
2. Develop Cost and/or Effectiveness Models. Models simply provide a means to obtain cost and effectiveness estimates for each alternative, so they can be compared with each other using the criterion	"The model is the description of the homeport requirements as defined in the memo from CINC, US Pacific Fleet: Homeport = Land + Ship Berthing & Movement + Utilities/Services + Ship Service + Housing + Base and Personnel Support. For the effectiveness model, each choice should meet all of the desired requirements. For the cost model, the investment cost to achieve desired effectiveness should be computed for each area of the homeporting requirement."
3. Conduct basic Quantitative Analysis. Appropriate data from the search effort is inserted into the model. Cost and effectiveness are calculated for the alternatives and results compared by the criterion. A quantitative preference is reached.	(See Figure 2 for results.)

FIGURE 2

EFFECTIVENESS MODEL

Model Elements		X = Alternative Meets Rqmt		
Item	Requirement	Long Beach	San Francisco	Seattle
Land	50 acres; perimeter fence and security guards.	X	X	X

Model Elements		X = Alternative Meets Rqmt		
Item	Requirement	Long Beach	San Francisco	Seattle
Ship Berthing & Movement	41ft. channel & berthing depth;176ft. overhead cl.; 3125'pier minimum-4475'desired.	X	X	X
Ship Utilities/ Service	150psi Steam--50,100lb/hr Electricity---20,200amps Fr.Water&Sewage-130Kgal/dy Salt Water--16,275gal/min Police, firefighting and refuse pick-up Telephone service(360prs)	X	X	X
Ship Service	Harbor services: tugs,fuel oil(1000gpm) Piers with 12ft wide lane 50ton mobile crane 100,000sqft.Int.Maint Area 160,000sqft. open storage/ with fence,lights,paving 60,000sqft.Pier warehouse 87,500sqft.storage area	X	X	X
Housing	Family Housing: 1-2 bedroom 1352 units 3 bedroom 482 units 4 bedroom 230 units Unaccompanied Enlisted: 50,000sqft.120rooms266beds Unaccompanied Officer: 16,100sqft.39rooms 39beds	X	X	X
Base & Pers. Support	2,400 parking spaces 25,500sqft.public wks area 87,500sqft.open storage 28,500sqft admin. space 15,000sqft medical clinic 8,500sqft dental clinic 6,500sqft community spt facilities. 160,000sqft morale, welfare, rec. facilities	X	X	X

COST MODEL

Model Elements	Cost of Alternative (millions of $)		
	Long Beach	San Francisco	Seattle
Land	2.82	0	0
Berthing&Movement	9.20	19.60	46.075
Utilities/Service	10.95	14.20	7.75
Ship Service	8.12	6.00	5.875
Housing	7.87	9.80	3.90
Base/Personnel Support	+ 19.55	+ 53.40	+ 18.40
Total Investment Cost	58.50	103.00	82.00
QUANTITATIVE ORDERED PREFERENCE:	1	3	2

Element	Response
4. Conduct Sensitivity Analysis. Entails repetition of the quantitative analysis to determine if a reasonable change in assumptions/estimates would change the preference for alternatives.	"What if the Army Corps of Engineers did pay to have the channel dredged in Seattle? The decision is sensitive to such a change in assumption. It would make Seattle $46.075M less costly. The quantitative preference would then be: 1. Seattle $35.93 mil. 2. Long Beach $58.50 mil. 3. San Francisco $103.00 mil."

Subjective Analysis

Subjective Analysis involves the explicit evaluation of all relevant factors, quantifiable and otherwise, which have not yet been addressed. Professional military judgment is a key ingredient to this part of the analysis.

Element	Response
1. Identify subjective factors. From the Key Factors, Search Phase and other areas in the analysis, we identify those relevant factors not yet considered.	"The three activities of this analysis can be handled together by a discussion of the factors in a narrative format." See Figure 3 for the Subjective Analysis.

Element	Response
2. Discuss each factor. Each factor is discussed to clarify its meaning and how to measure its impact on the alternative.	
3. Evaluate the impact on alternatives. This should include a statement (judgment) of how the alternative(s) are favored by each subjective factor.	

FIGURE 3

Identification of Subjective Factors, Discussion and Evaluation

A. Strategic dispersal and proximity to the SLOCs. This factor relates to the objectives of strategic dispersal and nearness to the sea lanes to Japan. Seattle is preferred by these factors, both because of its separation from other Navy ports and because it provides the shortest distance to the Far East. San Francisco is next best, followed by Long Beach.

B. Community support, is a prerequisite. Anti-nuclear activists are in all states; those in Seattle seem to be the most vocal. Some in San Francisco think the Navy's return would not be in the best long-term interest of the community. The assessment favors Long Beach and Seattle.

C. Nesting/expansion potential of piers. All alternatives provide the basic nesting capability as noted in the quantitative analysis. While nesting may be a "fact of life," the San Francisco option provides pier space for alongside berthing. Future expansion is also a benefit of this extra pier space not afforded with the other options.

D. Family housing is said to be the "most important non-operational item among homeport considerations." The basic quantitative analysis did not fully treat this factor. Housing must be affordable, of sufficient quality, and located within one hour of the base. If government housing most closely meets these criteria, then the San Francisco alternative seems the best with 100-150 units of government quarters on base and additional moderate income apartments built by the city. In second place is Seattle, where home construction with be subsidized by the state. Long Beach fares last in this factor because there are no provisions for government housing.

E. Quality of Life. This factor relates to the degree to which welfare and recreation facilities, plus logistical support are available to the potential homeport. In addition, it refers to the availability of shopping facilities, recreation and living support activities in the local area. All alternatives are equally favored by this alternative. Seattle has the infrastructure but it requires considerable renovation. San Francisco is reasonable close to the supply center at Oakland. Long Beach is within driving distance to the naval complex in San Diego.

F. Distance to the training areas is a factor which favors the alternatives in order of proximity: Long Beach, San Francisco and Seattle.

INTERPRETATION PHASE

This phase of the Decision Process involves the interpretation of the analyses and indicating preferred courses of action. More specifically, during the Interpretation Phase we attempt to accomplish four things. First, we try to get an overall perspective on the analytical results to date. Second, we devise a scheme for integrating and comparing the results of the quantitative and subjective analyses to arrive at an overall rank order preference among the alternatives (shown as the Summary Display.) Third, we assess the impact of other factors, external to the decision, which may affect the way in which the decision is made. Finally, we draw conclusions from all of the above and make recommendations, if appropriate, for the decision maker's consideration.

Element	Response
1. Interpret the Quantitative Analysis. Assessing the relative difference between alternatives, and the absolute value of resources to be expended.	"Considering the overall expenditure of funds for the SAG, the cost of any of the choices is reasonable. The relative difference between alternatives (21 to 44 million) is not considered an overriding factor."
2. Develop Summary Display of quantitative and subjective factors. This involves gathering all of the important factors previously considered and applying three judgmental activities: 1) combining the results of the previous analyses, 2) expressing the relative importance (weight) of the factors, and 3) arriving at an overall ordered preference.	"See Figure 4 for the Summary Display."

FIGURE 4

Summary Display

Factor	Relative Importance	Assessment of Alternative: 3=Hi; 1=Low Long Beach	San Francisco	Seattle
Quant. Analysis:				
Basic (Cost)	.40	$59 (3)	$103 (1)	$82 (2)
Sensitivity (dredge)		$59 (2)	$103 (1)	$34 (3)
Subjective Anal:				
Dispersal & SLOCs	.15	1	2	3
Community Support	.10	3	2	3
Extra Pier Space	.05	2	3	2
Family Housing	.15	1	3	2
Quality of Life & Infrastructure	.10	2	2	3
Training Areas	.05	3	2	1
OVERALL PREFERENCE		Third	Second	First

Element	Response
3. Interpret other elements in decision. Assess the preferred alternative in terms of three final considerations: 1) risk and uncertainty, 2) outside influences and 3) change in decision criterion.	"Risk & uncertainties: -ability to upgrade piers -extensive upgrading and new construction required -ability of state to fund commitments Outside influences: -pro nuclear freeze activists most vocal; supported by liberal Democrats -reaction of California political forces (President's home state) Change in decision criterion: no apparent reason to move away from optimizing approach to resource allocation."

Element	Response
4. State Conclusions and Recommendations. Based on all preceding analysis, conclusions are made regarding the ranked alternatives, how well objectives will be achieved and what risk is involved. The recommendation identifies the preferred choice, any additional study required and an initial look at implementation.	"All three alternatives can meet the homeporting objective. Long Beach does so at least cost, unless the dredging is done by the Corps of Engineers; then Seattle would be the clear choice. However, cost is not felt to be as important as the subjective factors. Quality of life, strategic dispersal and proximity to SLOCs favor the selection of Seattle. Long Beach and San Francisco appear to be very competitive for second choice. Very little risk seems apparent in any of the choices. Seattle is the recommended alternative. Further study should focus on solutions to family housing. Key to implementation will be strong political support in Congress, state funding and the timing of renovation of essential facilities."

IMPLEMENTATION & VERIFICATION

The activities of the Implementation and Verification Phase help to follow the decision as it moves from commitment of resources to operating system. Implementation is primarily concerned with controlling the events required to execute the decision, while verification measures the results of implementation and determines the degree to which the course of action meets the objectives.

Element	Response
Implementation:	
1. Establish a plan of action. A Management Control System will establish events, timing and sequence. Defined standards of quality must be set.	"Set up time schedule and sequence of following activities: -budget approval & execution -environmental impact statement -port development(dredging, piers, support)

	-facilities development(land, buildings, utilities, etc.) -housing (family, single)"
2. Organize as necessary. Identify individuals and organizations and insure both responsibility and authority to implement decision is assigned.	"Assign responsibility as follows: -NAVFAC; military construction -Personnel (OP-01): manpower assignments -Base Command structure -Operational Command structure -Type Commander Interface with local community and contractors."
Verification:	
1. Develop measuring tools. Decide on what and how to measure progress toward objectives.	"Establish standards and measure: -% of construction completed -quality assurance level -$ obligated versus $ spent -quality of life survey -housing survey; number and cost."
2. Establish control mechanisms. Develop Management Information System (MIS). Apply various testing methods to ongoing activities.	"Have project management team develop MIS and begin to collect data. Establish testing division."
3. Insure strong feedback networks. Tie in the results of verification to the control mechanisms of implementation.	"Establish responsibility within the project management to take corrective action or apply penalty to contracted activity. Use feedback to reprogram all necessary homeport development activities.

TOOLS FOR REVIEWING THE ANALYSIS

When one is finished evaluating alternatives and interpretation has led to specific conclusions, step back from the details of the analysis and review the entire effort to determine if it is complete and how well it fits together. This requirement may be achieved by simply going over the analytical effort one more time to see if the logic can be easily followed from beginning to end. It may involve the preparation of a briefing on the outcome or the development of a written analysis of the decision to be made.

A very useful approach to reviewing the completeness and comprehensiveness of an analysis is to ask a series of questions that focus specifically on each of the elements and concepts involved in the Decision Process. The emphasis is then placed on the process of decision making rather than the arguments and issues of the problem faced. Provided separately is a very helpful list of questions which have been developed over several years of working with this approach to making decisions in the Defense environment.

Another way to improve the quality of an analysis is to avoid the pitfalls that one can fall into. Each has the potential to sidetrack the effort, either by causing faulty analysis or souring the attitude toward the process itself. Here are ten of the most common errors.

1. Solving the wrong problem. Lack of attention to formulation, not clearly stating or "zeroing in" on the system objective, or confusing the investigative task with the real objective can all lead to solutions that miss the target. Emphasis on the decision to be made and the intended purpose for the resources will help keep the effort headed in the right direction.

2. Failure to use a systems view. Not viewing the resources and the decision involved as part of a system affects many essential parts of the process. We tend to be more concerned with how things work, rather than what is to be achieved. The relationship to higher systems and potential suboptimization may not be apparent without a systems view. More important, the development of good models for evaluating alternatives is very dependent on a systems view.

3. Not establishing a usable MOE and MOC. This is a vital and often underrated part of the process. Not selecting a measurable MOE, or at least the best possible, can lead to wasted data collection and eventually to solving the wrong problem. Frequently a point is identified rather than a scale on which all alternatives can be measured. Make sure that the MOE is the best possible way to measure performance of the system and try to avoid having multiple MOEs. Likewise, be certain that the MOC measures the right kinds of dollars when they represent resource use.

4. No systematic use of data. Data collection should be guided by relevancy, not by information that is collected, categorized and then ignored. Averaging values tends to mask useful data which could better be evaluated during sensitivity analysis. Even though the Decision Process promotes objective analysis, each time we choose a model, include or exclude a variable, use one set of data over another, we are making decisions that will influence the overall choice to be made.

5. Not developing or using an effective criterion. Although a decision rule may be used intuitively, an explicit criterion is frequently omitted or only partially stated. The lack of a rule for

deciding usually leads to unfairly evaluated alternatives. While a conceptual statement of criterion is helpful, it is better to state the rule in terms of the specific MOE and MOC. There are cases where one incorrectly tries to maximize effectiveness and minimize cost.

6. Weak analysis of the subjective factors. Because of overemphasis on quantitative analysis, time limitations or difficulty in doing the assessment, the impact of subjective factors on the decision are not properly evaluated. Why each factor is important is often not clarified by discussing the parameters and meaning. The impact of a subjective factor on each of the alternatives is not fairly determined.

7. Unsubstantiated Conclusions. There are many indicators of this pitfall. One decides on the course of action before the analysis is complete and tends to "force" the conclusion. The analysis is incorrectly interpreted and thus the conclusion does not track with the logic and results of evaluation. New data and factors are introduced to support conclusions that are not the logical outcome of the analysis.

8. Overlooking implementation in the Decision Process. Because implementation follows the point of decision, there is a tendency to not consider it until that time. The decision maker should plan for implementation and verification. The feasibility of alternatives may be determined to a great extent by the manner in which we can move from the decision to the operating system.

9. Failure to deal explicitly with uncertainty. Often there is the tendency, when an alternative is finally recommended, to forget the amount of uncertainty that was involved in the choice. Assumptions were made, estimates were used in the data, and judgments were applied to subjective factors. It is very important that the amount of uncertainty be explicitly identified when drawing conclusions and making recommendations, particularly recognizing the amount of risk that is inherent in the course of action being taken.

10. Not properly allocating time during the analysis. Rarely will the Decision Process be used in a situation where there is unlimited time to complete the process. Experience has shown that, unless time is carefully budgeted throughout the process, an inordinate amount of effort will be spent on the front end of the analysis and the pressure of a deadline will compress the subjective analysis, interpretation and implementation to a hasty and poorly thought out effort.

THE FUTURE

Everyone should develop a personalized approach to the Decision Process. There has been no intention to suggest that this

approach is the one and only way that objective and logical decision making can take place. But it does provide an initial start to deal with complex Defense issues. One may not be comfortable with the terms "decision situation," "criterion," or "summary display." Put whatever label is desired on the concepts. Just remember that each one of them represent a vital element in the structure of a rational decision. The customizing effort should have two goals: to make the process work smoothly in one's thought process, and be one which is understood and accepted by the decision maker and working peers.

There is no reason to think that decisions in the DOD are going to get easier. United States responsibilities in the world, the demands made by a mature society on its economic base and the complexities brought on by future technology all promise harder choices and more risk of failure. We certainly are gaining more capability to make better decisions, both from the geometric growth of computer support and a far greater understanding of the elements involved in those choices. But the factors that drive the difficulty of decision making higher seem to be outrunning the ability to cope with them. Everything from major weapon system procurement shortfalls and force-strategy mismatches to breakdown in contractor performance and overpriced hammers point to more challenging times ahead. Thus, there will be a continuing need to effectively allocate resources through the use of the optimizing techniques of rational decision making.

Defense Analysis has proven to be invaluable in the resolution of major Defense issues. In the Planning, Programming and Budgeting System it has been the major impetus toward objectively deciding on the best use of resources. However, in the past the lack of emphasis on professional military judgment has placed its contribution in doubt. Through adjustment and developed expertise a more comprehensive framework appears to be the best approach to future decision making in the Department of Defense. The melding of a workable decision process, the tools and techniques of analysis and the experience of the Defense executive will provide overall decision making with an the capability to handle all of the issues of national security.

APPENDIX A

CASE STUDY: HOMEPORTING THE SURFACE ACTION GROUP*

BACKGROUND INFORMATION

In anticipation of a 600 ship force by the end of the decade, the Navy has recently begun to look for additional port facilities to accommodate the additional 85 ships. Of concern is the berthing and associated support facilities for the first West Coast Surface Action Group (SAG) to be centered around the soon to be recommissioned battleship USS MISSOURI. Also included in the SAG will be a guided-missile cruiser, two guided-missile destroyers and a conventional destroyer.

Due to the Navy's new thinking on strategic dispersal and the already crowded conditions at existing Navy ports (San Diego, Pearl Harbor, and Alameda, Ca.) the decision has been made that the new port will be located in the western United States at either Seattle, Washington; San Francisco or Long Beach, Ca. An additional benefit of locating in the west is that the Navy can tap the vast industrial might of the area and at the same time spread the wealth of a highly lucrative business to the people of the area.

According to a high ranking Navy spokesman there are three prerequisites for port selection: first, community support for the ships, crews, and their families; second, strong and sustained political support reflecting and reinforcing the will of the people; and third, financial attractiveness.

Political support has been almost without exception, extremely favorable in all three locations and each congressional delegation is competing for the battle group as if it were a treasure fleet. In Long Beach, Dan Lungren, Republican member of the House Defense Appropriations Subcommittee has teamed with Governor Deukmejian, Mayor Bradley of Los Angeles and other public and financial leaders to ensure Long Beach is given due consideration. Long Beach having learned from past mistakes on similar issues, has decided to bid for the homeport by forming a solid political front.

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* This case was developed by Cdr. Roger J. Smith for The Defense Analysis course at the Naval War College. It represents a hypothetical scenario. The situation and the supporting data are solely for illustrative purposes and should not be interpreted as representing any past or present analysis by the Department of the Navy.

In San Francisco, Republican Senator Pete Wilson (former Mayor of San Diego) has been a strong proponent of the Navy and has been successful in rallying state support for the project, which had previously been stalled by a longstanding dispute between Navy Secretary John Lehman and California Democratic Senator Alan Cranston.

Likewise, Seattle has the backing of highly influential members of congress--Congressman Norman Dicks (House Appropriations Committee) and Senator Slade Gorton (Senate Budget Committee). Both have held private meetings with Secretary Lehman on the subject. Although Secretary Lehman has publicly pledged that politics are not going to be the determining factor in placing MISSOURI and its ships, recent action by the respective state delegations does not support his statements.

As political battle lines are being drawn, pro nuclear freeze activists in both states have become more vocal on the issue of having ships with nuclear cruise missiles located in their states. Although a force to be reckoned with, the base of the freeze movement encompasses all of the west coast and not just one or two areas. Seattle activists appear to be the most vocal, however. As a twist, it is indeed ironic to note that most of the liberal Democrats in the northwest who have been so adamant in their profreeze stances are now doing all in their power to attract the Navy to their port.

The possible return of the Navy to San Francisco is being viewed with mixed emotions by citizens and businesses who still have a bitter taste in their mouth over the Navy's pull out in which the area lost thousands of jobs and the associated payrolls. The following is an excerpt from the San Francisco Examiner which reflects the views of some citizens.

> It has taken the Bay area years to finally clean up the school, housing and bay pollution mess wrought by the Navy presence, and I'm not sure that the people of San Francisco deserve this on-again, off-again financial bonanza with our tax money. This area needs good, clean, desirable industries to move into the available space at Hunters Point, etc., and the "quick fix" of the big Navy money has glazed over the eyes of our politicians, so that safety, and long-term quality of life considerations have been overlooked.

In February 1985, the Navy sent a list of "homeporting requirements" to each of the three locations and asked that they respond with a written proposal addressing each of the seven areas of concern: land, ship movements and berthing, utilities, ship service, housing, base and personnel support, and quality of life.

SPECIFIC SITUATION

It is 0800, 18 July. After graduation from the Naval War College you have been assigned to the staff of the Deputy Chief of Naval Operations for Logistics (OP-04). Although the homeporting of the third Surface Action Group has been a matter of direct concern to your boss, most of the analysis in support of the decision has been done in the Navy Secretariat. The only official data available in OP-04 are the listed requirements from CINCPACFLT and the responses from the three prospective locations.

Vice Admiral Hill (OP-04) has just received a memorandum from the CNO's office (see attached). It indicates that the SECNAV intends to move up the time when the homeporting decision will be made and the CNO wants OP-04's advice on which port he considers to be the best choice. VADM Hill has his own thoughts on which location is the best for the Navy. Realizing that you gained a wealth of experience while in Newport, your boss would like you to perform a systematic analysis that formulates the problem in terms that are understandable, point out alternatives, evaluate these in a rational manner, and consider the non-measurable parts of this complex decision. Ideas on implementing the decision should also be included.

13 July

MEMORANDUM

From: Chief of Naval Operations
To: Deputy Chief of Naval Operations (Logistics) OP-04

Subj: Homeporting of Surface Action Group (SAG) on the West Coast

1. I understand that the three locations (Seattle, WA, Long Beach and San Francisco, CA) competing for the SAG homeporting have submitted their final proposals and that there is a wide range of cost estimates between the three ports. Although important, I want to ensure that cost does not become the only focus of attention as there are many other factors which must be considered in comparing alternatives. The Secretary has decided to move the announcement up to 30 July. It is in our interest to advise him what is BEST for the Navy.

2. Please prepare a comprehensive brief covering all aspects and present it to me at 0800, 25 July.

Enclosure (1)

15 May

From: Commander in Chief, U.S. Pacific Fleet
To: Chief of Naval Operations

Subj: Homeporting requirement for Surface Action Group

1. The following is a list of requirements for homeporting a Surface Action Group (SAG) consisting of one battleship, one guided missile cruiser, and three destroyers. A copy of these requirements has been sent to representatives of each of three ports under consideration.

2. Homeporting requirements

a. Land

In general, the Navy prefers eventually to own the land occupied by the homeporting mission. However, this is not a requirement at the outset. The size of the piece of land should be adequate (approximately 50 acres) to accommodate the necessary facilities, storage, and automobile parking. Space requirements for these various functions are given in subsequent paragraphs of this enclosure. A common requirement is the need for perimeter fences and security patrols. Proposed sites should be suitable for these features.

b. Ship Berthing and Movement

(1) The Surface Action Group is composed of five ships: one battleship, one cruiser, and three destroyers. A repair ship will occasionally visit the harbor to perform repairs on the five ships. Repair ship visits may last 4 to 6 weeks and occur semi-annually.

(2) The largest ship requires a navigational channel depth of 41 ft. at mean low water. The required minimum berthing depth is 41 ft. at extreme low water.

(3) The battleship also requires an overhead clearance of not less than 176 ft.

(4) All five ships and the visiting repair ship should be berthed at the same site. The Navy prefers that under ordinary conditions all five ships be moored to the pier and not nested. The table below gives dimensions of typical ships of the types to be assigned to the surface action group.

Enclosure (2)

The actual vessels except for the battleship are unknown at this time. Additional data is given for the repair ship.

SHIP/TYPE	LENGTH (FT)	BERTHING LENGTH (FT)	WIDTH (FT)	DRAFT (FT)
Battleship (BB)	888	1000	109	36.5
Guided Missile Cruiser (CG)	585	700	63	32.5
Destroyer (DD)	564	675	55	31
Guided Missile Destroyer (DDG)	564	675	55	31
Destroyer Tender (AD)	645	750	85	30

While individual berthing is preferred, nesting is a fact of life. An acceptable arrangement would be to nest one destroyer outside the cruiser and two destroyers together. The battleship should not be nested. The visiting repair ship would require mooring to the pier.

c. Utilities/Services

(1) While in port the ships' internal utility systems will be shut down and service provided from shore. The following table gives data on steam, electricity, fresh water, sewage, and salt water demands for each typical ship.

Ship	Steam at 150 PSI (lbs/hr)	Electricity 60 cy. 440 v. (amps)	Fresh Water and Sewage (gal/day)	Salt Water At 125 PSI (gal/min)*
BB	37,000	4,900	40,000	3,500
CG	5,100	4,100	13,000	5,700
DD	4,000	5,600	10,000	1,875
DDG	4,000	5,600	12,000	2,700
AD	**	**	55,000	2,500

* Salt water service will be provided at a capacity to satisfy the largest ship demand.

** The visiting repair ship will operate its own boilers and generators.

(2) Rail service to warehouses or pierside is not currently a requirement but will be utilized if available.

(3) The Navy will arrange for such services as police, firefighting, and refuse pick-up with the local municipality as necessary.

(4) Telephones will be required both in shore facilities and at pierside for service to ships. The phone service will eventually be both commercial and autovon. A total of 360 lines are required; 160 to serve the piers and 200 lines for the shore facilities.

d. Ship Service

(1) Harbor services, such as tugs, fuel oil delivery (1000 gpm), etc., should be readily available and will be contracted by the Navy when homeporting is initiated.

(2) The pier should be open and wide enough to allow a mobile crane, tractor trailer, or emergency vehicle to pass. This requires approximately two twelve-foot lanes the entire length of the berthing area.

(3) The lifting and weight handling requirements can be met by a combination of mobile and floating cranes. The Navy desires that a 50 ton capacity mobile crane be able to lift 40 tons to a vessel at pierside at any berth. The crane should be able to lift to a height of 160 ft. For lifts above 40 tons, a floating crane can be brought to the site. If nesting is considered, weights handled to the outer ship would be lighter in proportion to the distance from the pier.

(4) The area contiguous to the pier should have sufficient space to accommodate a ship intermediate maintenance activity of approximately 100,000 sq. ft. This space will be occupied by shops, store rooms, testing areas, offices, and administrative areas. Open storage/staging area of 160,000 sq. ft. with fence, lights and paving are also required.

(5) A warehouse of 60,000 sq. ft. is required in proximity to the pier. An open storage area of 87,500 sq. ft., paved and lighted, is also required near the warehouse.

e. Housing

(1) Family housing is the most important non-operational item among homeporting considerations. Housing must not only be affordable but must be of similar quality to that in other Navy ports. Sufficient housing must be located within one hour commuting time from the ship. This time should include normal delays for traffic. The following estimate is provided to describe the number of families who will seek housing in the civilian community if no government housing is available. Since there is little historical data on surface action group crews, this estimate is based on data from similar individual cruisers and destroyers.

Grade of Head of Household	Number of Families 1-2 bdrm.	3 bdrm.	4+bdrm.	Total
Officer	73	45	23	141
Enlisted	1279	437	207	1923
Total	1352	482	230	2064

NOTE: Housing/barracks in the Hunters Point area is sufficient to handle all requirements if renovated.

Members of the Armed Forces not living in military housing are paid a monthly housing allowance. The current government housing allowance in the Seattle, WA, San Francisco and Long Beach, CA areas are given below.

Ranges of Housing Allowance

Personnel	Long Beach	San Francisco	Seattle
Enlisted	$325-600	$320-625	$280-520
Officer	$535-800	$560-836	$459-700

(2) Personnel not seeking housing on the civilian market will be accommodated in barracks located on the home port site. At this time, the Navy estimates approximately 266 enlisted personnel and 39 officers will require space. The following unaccompanied enlisted/ officer personnel housing will be required.

Unaccompanied Enlisted Personnel Housing

Sq. Ft.	Rooms	Beds
50,000	120	266

Unaccompanied Officer Personnel Housing

16,100	39	39

In addition a 6,400 sq. ft. restaurant type dwelling facility will be required.

f. Base and Personnel Support

(1) Sufficient parking space is a high priority item in this group of support facilities. It is estimated that parking for 1,500 vehicles is needed to support commuters and space for 900 vehicles to support persons living on board ships. The latter group would require long-term secure parking while the SAG is deployed.

(2) Public works space is needed to support the shore facilities at the home port site. Approximately 25,500 sq. ft. of shop, office, and storage space is required. In addition, a paved, fenced and lighted open storage area of 87,500 sq. ft. is required in the public works area.

(3) Administrative space is needed for a variety of purposes. Principal among these are the homeport station administration, personnel support detachment, and communications center. The total required space is 28,500 sq. ft.

(4) Space is required to support a medical and dental clinic. An estimate of this space is 15,000 sq. ft. for medical and 8,500 for dental clinic.

(5) Community support facilities, composed of security police station and post office, will require approximately 6,500 sq. ft.

(6) Morale, welfare, and recreation facilities composed of exchange, commissary, recreation center, gymnasium, cafeteria, indoor courts, child care center, enlisted and officer clubs, and related facilities will require approximately 160,000 sq. ft. Outdoor recreational areas such as softball diamond, basketball and tennis courts are also desirable.

g. Quality of Life

Families will be coming into the communities surrounding the ship berthing area to use administrative, exchange and recreation facilities whether the ships are in port or not and therefore the quality of life in those neighborhoods is important.

3. The following additional information is provided to assist you in making a decision.

a. Harbors

(1) San Francisco Bay: perhaps the best deep-water port on the west coast. It is well protected and has a fairly straight and deep channel. Since the battleship requires a depth of 41 ft., dredging is required in the pier area and adjacent channel. From the Hunters Point area it is 12 NM to open ocean. There is one bridge with 294 ft. of vertical clearance. The bay has a normal amount of commercial shipping causing some freedom restrictions and safety in passage. Berths at Hunters Point can accommodate the entire SAG.

(2) Long Beach: Also a good harbor but is not as well protected or as deep as San Francisco Bay. Many small obstructions in bay. Channel and berthing spaces must be dredged. 7 NM to open ocean. No bridges.

(3) Seattle: a deep, well protected harbor with normal commercial shipping traffic. Berthing spaces need dredging. 14 NM to open ocean. One bridge with vertical clearance of 229 ft.

b. Access to Training Areas

Seattle is 570 NM farther from the southern training areas than Long Beach, and San Francisco is 265 NM farther. However, it is being said that as part of its strategic dispersal plan, the Navy will start training and operating more in the North Pacific where the sea lanes to Japan lie.

29 June

From: State of Washington Naval Homeporting Task Force
To: Secretary of the Navy

Subj: Washington proposal for homeporting of Navy Surface Action Group

1. It is with the utmost of pleasure that the State of Washington anticipates the arrival of a United States Navy Battleship to its shores. I think you will find the following proposal for the homeporting of your Surface Action Group in Seattle to be both fair and competitive.

a. Land: Washington will give the Navy 50 acres of waterfront. Navy's cost: $0.

b. Ship Berthing: Washington will give the Navy up to 3,200 feet of berthing on two former coal piers. The state will pay $2,305,400 to repair the piers. The channel must be dredged at a cost of $46,075,000. The state feels that Army Corps of Engineers might pay for dredging, but this is considered unlikely. Navy's cost: $46,075,000.

c. Utilities/Services: To meet Navy demands sites require improvement to existing electrical, water and steam facilities and construction of new sewers. Adequate rail service exists and police, fire department and garbage removal could be provided by Seattle. The state would pay $3,318,000. Navy's cost: $7,750,000.

d. Ship Service: Harbor services specified are available. Existing piers meet requirements but need improvement. Weight handling requirements can be met. Sites have adequate warehouses and open storage but will require the construction of a new ship intermediate maintenance building. Navy cost: $5,875,000.

e. Housing: Sites include no barracks and houses. Construction will be subsidized by the state. Navy's cost: $3,900,000.

f. Base and Personnel Support: Site has 17 acres of paved parking, an operating "public works" center, and building space for administrative and medical use. Most of these facilities require extensive renovation/modernization. Navy's cost: $18,400,000.

g. Quality of Life: The Seattle area has been the home of west coast naval forces, and a large Naval Station with shipyard facility. In all, these ships made up about 8,000 uniformed

Enclosure (3)

personnel and 6,000 civilians. Much of the infrastructure required to support a surface action group force is available requiring only renovation/modernization. The community adjacent to the proposed site is relatively small and access to and from the base by car is unhampered. The area should have no trouble in housing the approximately 3200 military personnel.

12 July

From: Port Authorities of San Francisco and Oakland, California
To: Secretary of the Navy

Subj: San Francisco Bay proposal for homeporting of Navy Surface Action Group

1. The people of the Bay area eagerly await the arrival of the United States Navy to their port. The offer which we are making in this proposal meets or exceeds all Navy requirements and we think should be financially attractive to the Navy.

a. Land: California will return to the Navy 50 acres on the western edge of the Hunters Point shipyard. Navy's cost: $0.

b. Ship berthing: California will pay for the reconstruction of two piers (length's 5,200 feet) including pier facilities and sheds. Berthing spaces need dredging. Navy's cost: $19,600,000.

c. Utilities/Services: Site would require the Navy to extend existing water facilities and install new electrical, steam and sewage facilities. Rail service could be made available and city, police, firefighting and sanitation already exists. Navy's cost: $14,200,000.

d. Ship Service: All harbor services are highly developed. Piers would be reconstructed to meet requirements. Lifting and handling capability is adequate. Site requires reconstruction of all ship maintenance and warehouse facilities while adequate open storage area already exists. Navy's cost: $6,000,000.

e. Housing: Site includes 100 to 150 housing units within Hunters Point. San Francisco will build moderate income apartments for rent by Navy personnel. Navy's cost: $9,800,000. Unaccompanied personnel housing will be renovated at no cost to the U.S. Navy.

f. Base and Personnel Support: Gym, parking, and chapel available at Hunters Point. Site requires renovation of administrative building and hospital. Navy's cost: $53,400,000.

g. Quality of Life: Community reaction to the Navy's presence in the area is highly favorable. The State and city are doing everything possible to make the area a good, safe place for Navy families to live.

Enclosure (4)

1 July

From: Economic Development and Industrial Office of Long Beach, California
To: Secretary of the Navy

Subj: Long Beach proposal for homeporting of Navy Surface Action Group

1. It is with great pleasure that the people of Long Beach await the return of a battleship to their port. We hope that the proposal which we have made meets with your satisfaction. We believe it to be both fair and competitive with other ports.

a. Land: Long Beach will sell the Navy 16.5 acres and return at no cost 31 more acres which the Navy leased to the Long Beach Port authority. Navy's cost: $2,820,000.

b. Ship Berthing: Long Beach will give up use of 3,500 feet of berthing space at a pier which the Navy owns but now leases to the Long Beach Port Authority. The channel and berthing spaces need dredging. Navy's cost: $9,200,000.

c. Utilities/Services: Site would require the Navy to improve electrical, water and steam facilities and construction of new sewers. Rail service is in place and metropolitan police, firefighting and garbage disposal are very effective. Navy's cost: $10,950,000.

d. Ship Service: Fully capable harbor services are available. Existing piers will be improved to meet all specifications. Weight handling requirements can be met with the exception of a floating crane (pierside lift capability is 60 tons). Site requires improvement to ship intermediate maintenance and warehouse facilities. Adequate open storage area is available. Navy's cost: $8,120,000.

e. Housing: Site includes facilities which can be improved for use as a barracks. No government housing is available. Navy's cost: $7,865,000.

f. Base and Personnel Support: Site requires improvements to a garage and building space to house public works, recreational, administration, and medical functions. Navy's cost: $19,545,000.

g. Quality of Life: Community reaction to the Navy's presence in the area is highly favorable. The communities are safe and affordable housing is located within one hour commuting time.

Enclosure (5)

APPENDIX B

(A series of questions that can assist in checking an analysis)

FORMULATION PHASE

1. Decision Situation.

- What is the difficulty or opportunity that stimulates the decision maker to make a choice among alternative courses of action?

- Is the difficulty or opportunity defined and stated realistically?

- Can one identify a "gap" between the current situation and the desired goal?

2. Decision Maker.

- Who is the decision maker that controls the resources involved in the decision?

- What perspective would his or her view bring to bear on the decision to be made?

3. System.

- What is the functional system to be considered?

- What higher, collateral, and lower systems are involved?

4. System Objective.

- What is the system intended to achieve?

- Is it consistent with higher level systems' objectives?

- Does it impact objectives of other systems?

5. Measure(s) of Cost (MOC) and Effectiveness (MOE).

- How can one measure the achievement of the system objective? What scale will best indicate the effectiveness produced by an alternative?

What are the costs involved in achieving the system objective?

- Are they more properly measured in dollars or some other indicator of resources being consumed?

- Is more than one measure of effectiveness or cost necessary?

6. Key Factors and Assumptions.

- Have all of the key factors that will affect the decision been identified? Are they grouped together so that they will be readily available later in the Decision Process?

- Have basic assumptions been made to arbitrarily establish the values for uncertainties, choose the specific numbers for all critical variables and set the boundaries of the analysis?

SEARCH PHASE

1. Alternatives.

- Are all the viable alternatives considered? Even the ones which challenge "sacred cows" and parochial viewpoints?

- Have the irrelevant and infeasible choices been discarded?

- Is there an explanation for the omission of any "apparent" courses of action?

- Has the status quo been considered?

- Are all the alternatives being considered able to satisfy the system objective?

2. Data.

- Is the collected information relevant to the decision situation?

- Are data for the Measure of Effectiveness and Cost available and reasonable?

- Are missing relevant data identified for collection as additional time and resources permit? Are data needs prioritized?

- Have assumptions been made to cover missing relevant data?

EVALUATION PHASE (QUANTITATIVE ANALYSIS)

1. Criterion for Quantitative Analysis.

- Have effectiveness and cost been combined to state a useful guide for establishing a preference among alternatives?

- Does the criterion clearly reflect achievement of the objective?

- Does the criterion specifically use the Measure of Effectiveness and Measure of Cost?

- Will cost be minimized for a fixed level of effectiveness or effectiveness maximized for a fixed level of cost?

2. Models.

- Are the system's essential quantitative characteristics represented in the structure of the model?

- Do the models capture the quantitative essence of the real situation in a logical pattern that the general reader can understand?

- Do the models clearly show the consequences of each alternatives in terms of effectiveness and cost?

- Are uncertainties about specific model variables resolved by reasonable assumptions or estimates?

- Are quantitative factors that do not fit into the models identified for consideration in the subjective analysis?

3. Basic quantitative analysis.

- Does the effectiveness model output values that are common to all alternatives?

- Are all alternatives compared by the same set of effectiveness measures?

- Are relevant costs identified explicitly and are non-relevant costs such as sunk and common costs excluded?

- Has the cost model given appropriate consideration to life cycle costs?

- Is the time value of resources (present value) a factor to be considered in the comparison of alternatives?

4. Sensitivity Analysis.

- Are the key assumptions subjected to sensitivity analysis to assess the impact of a change in their value on the choice of alternatives?

- How much change in the value of an assumption can be made before it affects the preference for alternatives?

EVALUATION PHASE (SUBJECTIVE ANALYSIS)

1. Identify Subjective Factors.

- Are there other quantitative factors not included in the models which would affect the choice of alternatives?

- Can the various organizational, bureaucratic and political factors which have been identified be objectively discussed within the context of a rational model?

- Have we avoided bias in the determination of which subjective factors are relevant to the decision?

2. Discuss each factor.

- Has each subjective factor been clarified by describing its qualities, range of impact and relationship to the decision?

- What spillover effects (benefits and costs in addition to those intended) are likely with each alternative?

3. Evaluate Subjective Factors.

- Has the impact of each factor on each of the alternatives been fairly assessed?

- Has double counting occurred by considering the advantage of a factor to one alternative to be the detriment of another choice?

- Are the results easily understood? Can the relative differences between alternatives be clearly summarized?

INTERPRETATION PHASE

1. Interpret the Quantitative Analysis.

- Is the quantitative difference between alternatives significant?

- Are the overall values for effectiveness and/or cost reasonable and sufficient to achieve objectives within acceptable resource expenditures?

2. Summary Display of quantitative and subjective factors.

- Are all significant quantitative and non-quantitative factors summarized for a clear interpretation?

- If the factors were weighted, did you explicitly consider the importance of each factor in the decision?

- Can the alternatives be rank ordered by the factors in the summary display? In an overall evaluation?

3. Interpret other elements in decision.

- How much uncertainty is involved in the evaluation of the preferred alternative?

- What amount of risk will the decision maker assume by selecting the preferred choice?

- Are there organizational or bureaucratic pressures that will limit or influence the way the decision is made?

- Will the decision maker use optimization as the criterion for decision or will other decision rules form the basis for choice?

4. State conclusions and recommendations.

- Are the conclusions consistent with and supported by the analysis?

- Are the major uncertainties that remain after the analysis, and other problem areas discovered during the analysis, identified for further study?

- Are the recommendations for a decision practical and defensible?

- Can the recommended course of action be implemented?

IMPLEMENTATION AND VERIFICATION PHASE

1. Implementation.

- Have you reviewed all of the activities of the Decision Process where implementation should have been considered?

- What types of plans will insure the decision is carried out?

- Who is the individual(s) responsible for execution?

2. Verification.

- Is your objective specific enough to define standards to test the reliability and validity of alternatives?

- Is there an existing structure for testing and verifying, or must one be established?

END
DATE
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